1-1-2020

# 06 Exam 2 Take Home

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Chem 444A, Spring 2015, Exam 2 CFBauer Your Name: ____________________________

Exam 2 is a take-home exam. It is due at my office (Parsons W108) or my Chem office mailbox (Parsons W115) by 4:30 pm Friday April 24. You may also deliver it to me electronically.

The exam covers predominantly the material since exam 1, but may overlap a bit with the early concepts unavoidably. The questions relate to the concepts and topics we discussed in class, so your primary resource is your own class notes, and the collective information on Blackboard.

There is no prohibition on use of resources. You can consult anything or anyone except the other students in class. However, all answers must be a construction of your own thoughts and words. The questions are intended to make you think and integrate ideas. You may not find a "ready answer" out there.

The exam is equivalent in length to the last one. I would expect it could be finished comfortably in two hours.

All responses should be legible, in grammatically correct sentences, and have an organized structure. Your goal is to use fundamental ideas in your response. Stronger responses will use those ideas more thoroughly and sensibly, describing WHAT but also HOW the phenomena occur.

Each problem is 5 or 10 points as noted.

Christopher F. Bauer, Principal Investigator. This material is based upon work supported by the National Science Foundation under Grant No. 1235730. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. 

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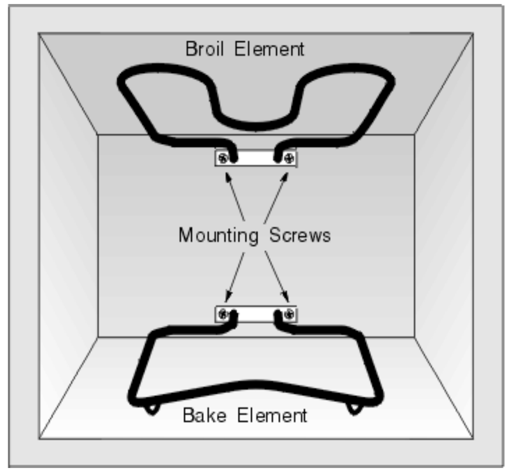
Questions 1 to 4 are about cooking

Inside a conventional electric oven is a "heating element" on the bottom, and another "heating element" on the top. Here is a picture:




1. When you "turn on" either of these elements, you will observe over time that the element at first looks unchanged although the air temperature inside the oven is increasing, then the element gradually starts to glow. First, it will be red. Later it will become orange or yellow. Explain where the heat and color progression of the glow come from. (10 pt)

2. To bake bread, you put dough in a metal container (like this)

And turn on the lower element to "bake" the bread.

To cook a steak, you put the steak on a metal sheet (shown to left) and turn on the upper element to "broil" the steak.

Compare and contrast baking and broiling in terms of how heat energy gets from the heating element to the material being cooked. (10 pt)

3. Baking cookies. You put cookie dough onto a flat metal tray inside the oven, and turn on the lower heating element. A simple metal tray often leads to burning the bottoms of the cookies while you are waiting for the tops of the cookies to get "done". Good bakers know that a better cookie tray has two layers of metal separated by a narrow air gap. The cookies on this tray don't burn – they are cooked just right throughout. Explain why the difference in the results. (5 pt)

4. Boiling water to make tea. Compare boiling water in a traditional tea kettle (shown here) and boiling water in a microwave oven. The kettle is placed on top of the oven on a circular heating element. The microwave oven brings water to a boil much faster (2 min compared with 5-10). Explain how the water is heated in both cases and why the microwave is faster. (10 pt)

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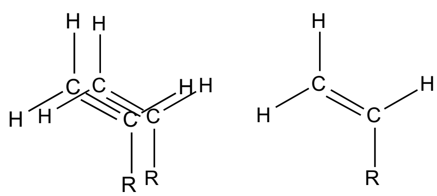
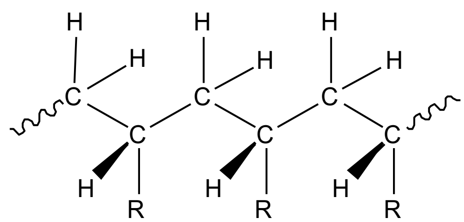
Questions 5 and 6 are about automobiles.

5. Bondo is a commercial product used to repair holes in the exterior body of cars, e.g. rust holes. It is a thick sticky liquid, but you mix it with a "hardening agent" and that converts the liquid into a solid over about 15-20 minutes. So, you take a "handful" of the liquid, mix in a few drops of the hardening agent, and then use a putty knife quickly to transfer the paste, and mold and shape it over the hole. The liquid is primarily a substance called styrene. The "hardening agent" starts a process which converts the styrene into polystyrene, which is a solid. Both structures are shown below.

This shows 3 molecules of styrene. R is a complex group of atoms that are not affected by the process.





This shows the polystyrene segment that comes from three molecules of styrene. The squiggly lines at the end of the polystyrene indicate that the chain of C atoms continues (if more styrene molecules are involved). The chain can be 100s of units long.

Here's the question (finally): One time I was repairing my car and noticed that the paste as it was hardening was warmer to the touch than it had been at the start. I confirmed this with a thermometer.

5a. Is there a chemical reaction going on here? Justify your answer. (5 pt)

5b. What is the source of the heat? A better answer will include a quantitative argument. (5 pt)

6. Most cars have a "radiator", made entirely of metal, like this:

You fill it with water (or a special "coolant" solution). A pump circulates the water into the bottom and out the top, and then through metal pipes (not shown) that attach to the engine, and back to the bottom of the radiator again. The flat part of the radiator is a honeycomb structure. Air can move through that honeycomb. The radiator is normally placed at the very front of the engine compartment. The engine produces heat when it is running.

a. Explain how the radiator protects the engine from overheating. (10 pt)

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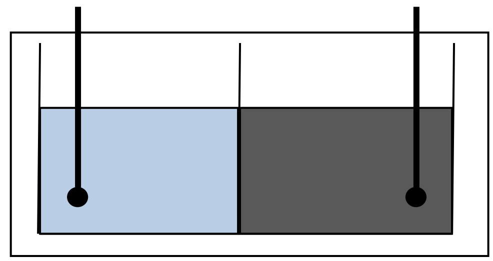
b. Suggest two conditions under which this system might fail to protect the engine. Explain why those conditions would cause a problem. (10 pt)

7. Consider this scenario.



Two containers share a common wall.
Identical thermometers are in each.
The container on the left contains water.
The container on the right contains mercury, a liquid metal.

The wall separating the containers is a substance that does not react chemically with water or mercury, and it has modest thermal conductivity. The box shown surrounding the container indicates that the materials on the inside are thermally isolated from the rest of the lab.

a. Assume the water and mercury had been sitting out on the lab bench since yesterday. Describe what you expect the temperatures of the two liquids to be just after pouring them into the containers. Explain your expectation. (5 pts)

b. Assume that you had removed the mercury from a refrigerator, and had warmed the water in a microwave before. Then you poured the liquids into the container above. The initial temperature of the water is 55 °C and mercury is 5 °C. Sketch a graph showing both temperatures over time. Label appropriately, but only worry about qualitative accuracy not quantitative accuracy. (10 pts)

c. Another students says: "I expect the mercury to reach its final temperature more quickly than the water will because mercury as a metal is a better heat conductor". Do you agree or not with this statement? Explain. (5 pts)

d. The number of molecules or atoms per unit volume is slightly larger for mercury vs water. Nevertheless, the final temperature will be about 40 °C, closer to the initial temperature of water. Explain how that could result. (5 pts)

8. Water beds were common in the 70s. They had a number of drawbacks: they are really heavy when filled (structural problem in a house), if they spring a leak there could be serious water damage, and it's necessary to circulate and heat the water, otherwise sleeping on an unheated water bed is very uncomfortable. Explain why unheated beds were uncomfortable for sleepers, using fundamental principles. (10 pts)

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Exam 2 Answers

1. When you turn the oven on, the broil element and the bake element themselves will be subjected to electric heating because the oven is powered by electricity. Electrical heating is the process in which electrical energy is converted into heat. However, this does not explain why the temperature inside the oven increases. The increase in temperature inside of the oven is due to a form of heat transfer called radiation. Radiation is the emission of energy in the form of electromagnetic waves. Energy in the form of electromagnetic waves is being emitted from these heating elements. These electromagnetic waves will begin hitting the sides of the oven, and the sides of the oven will absorb the energy and the energy will be converted to heat. Because an oven insulates heat inside of it, the air temperature inside of the oven will increase. The hotter that you make the heating elements through control of the temperature dial on the oven, the higher the frequency of these waves become. In turn, these higher frequency waves will cause the inside of the oven to get hotter and hotter.

   When you turn the oven on, eventually you will also notice that the heating elements will gradually start to glow red, and then eventually orange. To understand this phenomena, we must understand that the atoms in objects will vibrate when they receive thermal energy from another source. In this case, the source that the elements are getting energy from is the electricity. The more energy that an object receives, the faster the atoms will vibrate. Like I explained in my definition of radiation, these vibrating atoms will give off electromagnetic waves. Humans can only see a very small sliver of all of the electromagnetic waves that there are. The colors that we can see range from red to violet, and the color we see also depends on the frequency of the wave. Red has the lowest visible frequency and violet has the highest. Cooler objects emit lower frequency wavelengths and warmer objects emit higher frequency wavelengths. The increase in temperature of an object will result in higher frequency wavelengths because of the increase in the vibrations of the atoms. This is why, when the heating element gets to a certain temperature, we see it as red. From red, as the temperature continues to increase, along with the frequency of the wavelengths, we will eventually see the heating element as orange or yellow. The reason that we don't see the glow when we initially turn the oven on is because the frequency of the waves was not strong enough and therefore invisible to the human eye.

2. To bake bread you put your dough in a metal container and you would turn on the lower element, which is the baking element. To cook steak you would put the steak on a metal sheet and turn on the upper element to broil it. First, let's explain why we put our dough or steak on or inside of a metal container/sheet. We generally use metal in cooking because metals conduct heat better than most other solids do. Heat is the transfer of kinetic energy between atoms. The electrons in metal are not stuck to the atoms, which means the electrons flow freely. This means that as they gain energy, they vibrate more quickly, and because they have the ability to move freely, they can pass on energy more quickly. This good conductivity of heat lets us cook things more quickly. The container acts like a barrier between the dough and the heating element. Having a metal container lets the heat get to the dough. If the container was something less conductive, it would take longer for the thermal energy to pass through the container to heat the dough. When cooking bread on the lower baking element, the heat transfer that is taking

place is conduction. Conduction is the direct transfer of thermal energy from a warmer substance or body to a colder substance or body. There will be a transfer of kinetic energy from the heating element to the metal container surrounding the dough. The atoms in the container will begin to vibrate in a fixed position as they receive thermal energy from the heating element. Eventually the kinetic energy from the container will be transferred to the atoms in the dough, and as the atoms in the dough begin to vibrate, the dough will cook. Generally, bread is something that you want cooked all the way through, and that is why you use a container as opposed to a flat sheet, and that is also why you put it on the bottom. Having a metal container surrounding the dough will cook it not only from the bottom up, but from the sides as well, which allows for a more even cooking.

The process of broiling involves heat transfer by both conduction as well as radiation. Neither the steak or the metal sheet is in contact with the broiler on the top, so in order for the sheet and the steak to attain heat, the electromagnetic wave that are radiating from the top broiler must come into contact with the steak and the sheet that it is on. When the waves of energy hit the steak, that energy will be converted to heat, and the steak will begin cooking. The energy in the electromagnetic waves provides kinetic energy to the atoms in the steak, and that is where the heat comes from. The steak will also be cooked when the sheet that the steak is being cooked on is heated by radiation. The sheet will become hot when it absorbs energy from the electromagnetic waves, and because the steak is in contact with the metal sheet, heat transfer by conduction will take place, and the stake will cook from the bottom. In both baking bread and cooking steak, we see heat transfer by conduction, but when cooking steak, the primary source of heat is coming from the radiation from the top broiler. This allows you to cook the top and bottom of the steak, but you don't usually want to cook steak as thoroughly as you cook bread, so that is why you use the broiler. Because the steak isn't in direct contact with the heating element like the bread, the steak won't be as cooked through, which is what you want.

3. If you bake cookies on a flat metal try inside of the oven, there is a good chance that you will burn the bottoms of the cookies while you are waiting for the tops of the cookies to finish cooking. Cookie trays with two layers of metal separated by an air gap do a much better job of baking the cookies evenly. When there is only one layer of metal, heat is transferred by conduction to the metal tray, and then directly into the bottom of the cookies. Kinetic energy from the atoms in the heating element collide with the atoms in the baking sheet. The atoms in the cookie sheet will begin to vibrate. The kinetic energy in the cooking sheet will eventually transfer into the bottoms of the cookies. The bottoms of the cookies are in direct contact with the hot baking sheet, so the thermal energy will travel very quickly because metal is a good conductor of heat. A lot of thermal energy will reach the bottom of the cookie quickly, and so the bottom of the cookie will cook faster because the thermal energy hasn't had time to flow through the cookie. A cookie sheet with an air buffer between two layers of metal will allow the cookie to cook more evenly. When there is only one layer of metal, there is nothing to reduce the transfer of heat. An air buffer would act as an insulator of heat, and what this does is it reduces the transfer or passage of heat. In this case, thermal energy would have to travel through two layers of metal before it begins to bake the cookie. Less heat will reach the bottom

of the cookie at such a fast rate, so there will be more time for the thermal energy to flow through the cookie, cooking it more evenly.

4. When you boil water on a stove, the water is being heated by conduction and convection. The kinetic energy from the atoms in the stove top is transferred to the atoms in the tea kettle. The atoms in the tea kettle will begin to vibrate, and then the kinetic energy from the atoms in the tea kettle will transfer into the atoms in the water. As the water begins to gain heat, it will rise because its density is decreasing. The hot water is less dense because atoms in hot water have more kinetic energy so they are moving faster and are more spread out. As the warmer, less dense water at the bottom begins to rise, the cooler water from the top will sink to replace it. Cooler water is less dense than warm water because the atoms are moving slower and are more clustered together. As this water gets heated, it will rise and the cycle will continue. Eventually the cycle will get more violent as the water gets hotter and the convection current gets stronger. This is why water takes on a rolling motion when it boils. So to summarize, the tea kettle is heated by conduction, and heat transfer by convection causes the water to boil. When you put the tea kettle of water into the microwave, the water is heated through radiation. Microwaves use electromagnetic waves to heat food from all angles. The water in the tea kettle will absorb these electromagnetic waves, and it will cause the water molecules in the water to start vibrating until they come to a boil.

   Putting the tea kettle in the microwave is going to bring water to a boil faster than if you try to bring water to a boil on a stovetop. When you heat something by conduction, the heat travels from the bottom up. To bring water to a boil, you have to excite all of the water molecules in the tea kettle, but the thermal energy goes from the heating element beneath the tea kettle, to the bottom of the tea kettle, up through the water. Essentially, the heat has to migrate from the outside to the inside. When you put the tea kettle inside the microwave, the water is heated faster because electromagnetic waves used for heating penetrate the water all at once. Heating through conduction takes a longer time because the process of getting heat to all of the molecules takes longer. On the other hand, when the water molecules are excited on all sides, which what happens during heat transfer by radiation in a microwave, heat is essentially everywhere at once, which is why the microwave heats water faster.

5. A) There is a chemical reaction taking place when you mix the hardening agent with the Bondo. A chemical reaction takes place when you mix two substances together, and the atoms in these two substances rearrange themselves to form a new substance. Essentially it is the change in the chemical properties of the substances. There are numerous indicators as to whether a chemical reaction has taken place within a solution. If the solution changes color, if a solid precipitates, if the solution begins to bubble (if this happens then the product of the reaction is a gas), or if there is a temperature change due to the reaction, then there is a chemical reaction taking place. Based off of the information given, when you mix the Bondo and the hardening agent, the temperature of the solution increases, and the solution becomes a solid. Because we saw a solid precipitate, and witnessed a temperature chance, we can make the statement that a chemical reaction took place.

B) Because the solution is giving off heat when you mix the Bondo and the hardening agent together, we know that an exothermic chemical reaction is taking place. For a chemical reaction to take place, existing bonds must be broken and new bonds must be formed. When existing bonds are broken, energy is taken from the environment to break the bonds. When new bonds are formed, energy is released. If the bond energy of the product is greater than that of the reactant, we know an exothermic reaction is taking place. If the bond energy of the product is less than the bond energy of the reactants, we know an endothermic reaction is taking place. Because you can feel the increase in temperature in the Bondo/hardening agent solution, more bonds are being formed than are being broken, so more energy is being released than absorbed, so the temperature rises. You can also see how this makes sense using a quantitative argument. What is happening when styrene becomes polystyrene is the act of polymerization. In other words, the three styrene monomers are being converted into a polymer. For this transformation to take place, first the styrene monomer's double bond ( C = C ) has to be broken. Remember, this will cause energy to be absorbed. Once the double bond is broken, a new single bond will form between the carbon atoms ( C - C), and there will also be a single bond connecting two styrene monomers together to make the polystyrene. Remember, when bonds are formed, energy is released. Now, to break the double carbon bond it takes 10.2 (10^-19 Joules) of energy. We know that once the double carbon bond is broken, two single carbon bonds are formed. To form a single carbon bond it takes 5.8 (10^-19 Joules) of energy. A double carbon bond being broken absorbs 10.2 and two single carbon bonds being formed releases 5.8. 5.8 + 5.8 = 11.6. When two single carbon bonds are formed, 11.6 energy is being released as opposed to 10.6 being absorbed with the double bond is broken. As you can see, more energy is being released when polystyrene is formed, which explains where the heat is coming from, and why this is an exothermic reaction.

6. A) The radiator protects the car engine from overheating through both conductive heat transfer and convective heat transfer. Because the engine produces heat when it is running, the water or the "coolant" solution will heat up before it enters the radiator. When the water enters the radiator, initially, it will begin being cooled because of conductive heat transfer. This is why most radiators are made out of metal. Metal is a good conductor of heat. The thermal energy from the hot water will transfer into the cooler metal. The hot water molecules will be vibrating fast, and they will collide with the atoms in the metal. This collision will cause a transfer of kinetic energy. As the water molecules lose kinetic energy, the temperature drop. When the water loses thermal energy, it will be cooler when it gets pumped back into the engine, preventing the engine from overheating. The other way that the water is cooled is through convective heat transfer. The honeycomb structure of the car radiator lets cool air pass through the radiator. The hot water transferred heat into the metal radiator through conduction, and the cool air passes through radiator. As the cool air passes through the radiator, thermal energy is transferred from the metal radiator into the air. The hotter air becomes less dense and floats away, and more cool air will come down and blow through the radiator taking more thermal energy and cooling the radiator off even more. This flow of air creates a convection current. It is important for the metal of the radiator to cool down because it has been taking thermal energy

from the water. If the metal doesn't cool down, the metal will eventually become the same temperature as the water, and there will be no more heat transfer. As we can see, the combination of heat transfer by conduction and convection in the radiator is what protects the car's engine from overheating.

B) The first condition under which this system would fail to protect the engine is if the air flow that was allowed to move through the radiator got constricted. The air flow is important because this air is cooling off the metal of the radiator. As I stated above, the metal radiator is absorbing heat from the water to cool the water. The radiator will only absorb heat from the water as long as the metal is cooler than the water, because thermal energy always travels from a hotter body to a colder body. Without the air flow, the metal radiator won't get any cooler. The metal radiator will keep retaining heat, and eventually it will become as hot as the water. If the metal is as hot as the water, the metal won't absorb heat from the water, and the water won't cool. If the water doesn't cool, then the result will be the engine overheating. Another condition in which this system might fail is if the metal on the radiator begins to rust. This is a common problem with a lot of radiators. With water and coolant flowing through the radiator so often, it makes sense that the radiator will eventually rust. First of all, rust could cause clogging within the radiator. Clogging could prevent the flow of water through the radiator, which will cause the engine to eventually overheat. Another problem with rust is that it does not conduct heat like un-rusted metal does. Rust is an insulator of heat. The radiator relies on the metal absorbing heat from the water or coolant to cool the engine. If the metal is not absorbing heat because the metal is rusted, than there will be no transfer of thermal energy from the water to the radiator. If this happens, the hot water will be reintroduced to the engine and the engine will overheat. In conclusion, the two conditions in which this system might fail is if there is no air flowing through the radiator or if the radiator gets rusty.

7. A) I would expect the temperatures of the liquids to remain at whatever temperature the room they were sitting in is. Normally, if one liquid is hotter than the other liquid, the energy from the hotter liquid would flow into the colder liquid and it would reach a thermal equilibrium. However, the question states that both the water and the mercury have been sitting on the lab bench since yesterday. Because they have been sitting on the lab bench for so long, both liquids are going to be at room temperature, which means they will have the same level of thermal energy. If they both have the same level of thermal energy, there will be no transfer of heat between them because energy only travels from a hotter body to a colder body. When objects are the same temperature, there is no heat transfer. This is the zeroth law of thermodynamics. This means that the temperature of the two liquids after just pouring them into the containers would be whatever the temperature of the room is.

   B) See attached sheet for graph.

   C) I do not agree with this statement. If you poor two liquids of different temperatures into containers that are connected side by side with each other, based on the zeroth law of thermodynamics, both liquids will eventually reach thermal equilibrium. This is when energy from a warmer body flows into a colder body. The temperature of the warmer body will begin to drop as it loses kinetic energy, and the temperature of the colder body will begin to increase as the atoms gain kinetic energy. Since the water is the hotter body, thermal energy will flow from the water into the mercury. The statement that the student makes is that mercury will reach its final temperature (thermal equilibrium) before the water does because mercury is a better conductor of heat. While the student is not wrong in saying that mercury is a better conductor of heat because it is a metal, that factor has no bearing on how fast mercury reaches equilibrium with water. Water is the substance giving thermal energy to the mercury because the water is the warmer body. The mercury can only absorb the energy that the water gives it. That means that mercury can only absorb thermal energy at the same rate that the water releases it. What this means is that the temperature of the mercury will rise at the same rate that the temperature of the water falls. Conductivity doesn't matter because as long as mercury is absorbing energy, water is releasing it. The transfer of energy will only stop once the two liquids are the same temperature. The water and mercury have to reach thermal equilibrium at the same time. Even though mercury conducts energy better because it's metal, it can only absorb energy at the rate that water releases it.

D) Even though the number of atoms per unit volume is larger for mercury than it is for water, the final temperature can be closer to the initial starting temperature of water if one container contains a significantly larger amount of water than the other one contains mercury. Remember, according to the zeroth law of thermodynamics, energy transfer will only continue to take place if one substance is hotter than the other substance. As soon as they are equal in temperature, heat transfer will stop. Now imagine that there is a significantly larger amount of hot water than there is cold mercury. This means that there are a lot less mercury molecules than there are hot water molecules. Overall, because there are more hot water molecules than cold mercury molecules, the hot water will have more thermal energy to share with the mercury molecules, and the resulting equilibrium temperature will be much closer to that of the hot water. If there were more cold mercury molecules than hot water molecules, there would still be a transfer of thermal energy from the water to the mercury, but the heat would be dispersed in a much more spread out manner, and the resulting thermal equilibrium would be closer to that of the colder mercury.

8. Unheated water beds are uncomfortable for sleepers because if the water is colder than the body temperature of the person laying on it, the water will absorb the heat from the person's body, leaving the person feeling cold and uncomfortable. This is another example of thermal dynamics and how heat flows from a warmer body to a colder one. The heat transfer taking place in this is heat transfer by conduction because the person is in direct contact with the bed. The atoms in the body are moving faster because they have more kinetic energy. The atoms in the water in the water bed have less kinetic energy, so they are colder. When the atoms collide, and kinetic energy is transferred, the atoms in the body lose kinetic energy, so the person will begin to feel colder while they are sleeping. Because a waterbed is so big, there are probably a lot more cold water molecules, so the thermal equilibrium that is reached is going to be a lot

closer to the initial temperature of the water bed than the temperature of the person. That is why sleeping on an unheated waterbed was so uncomfortable.

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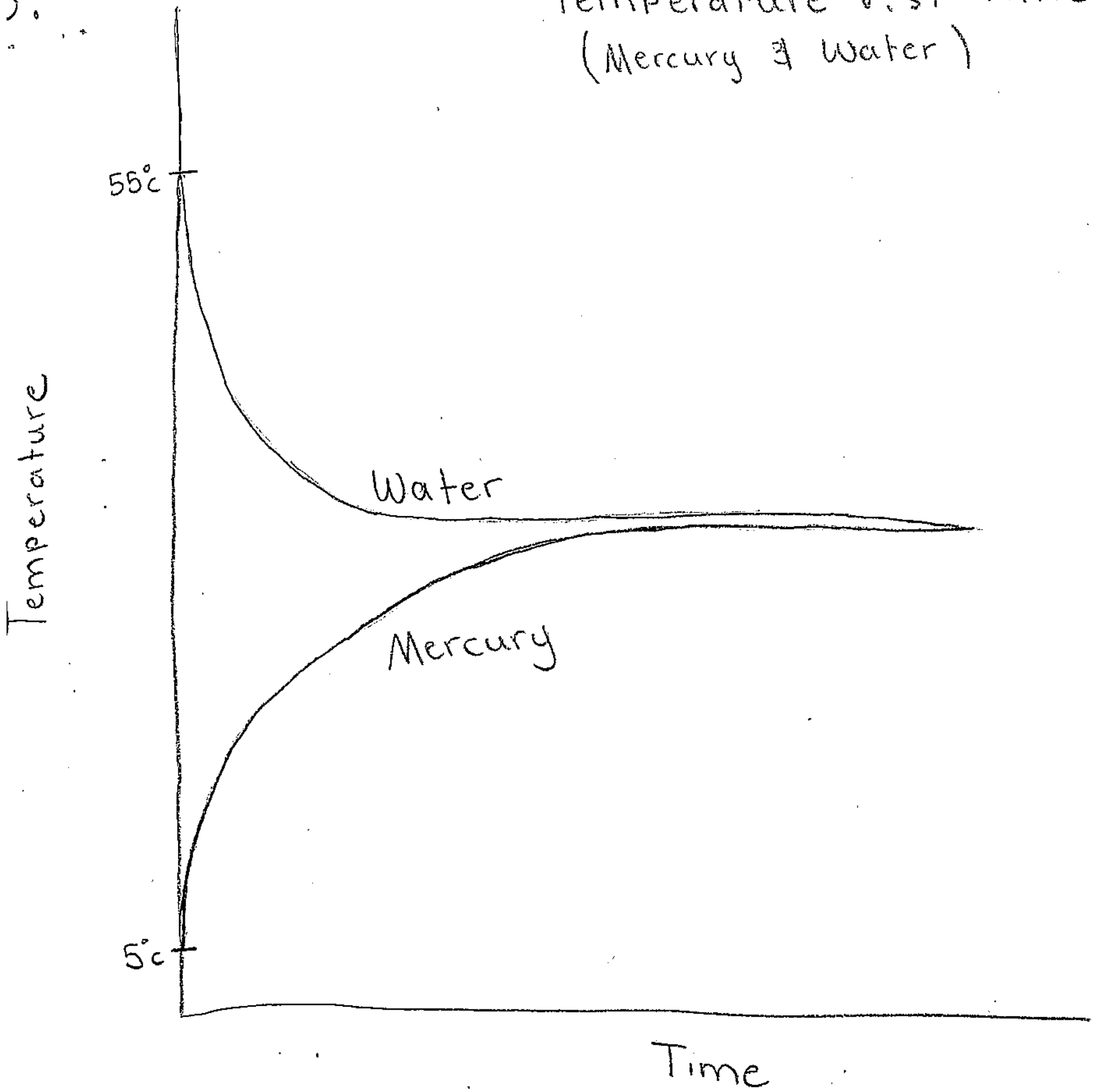
Temperature V.S. Time
(Mercury & Water)

B26



C37

CHEM444A Fire and Ice
Exam 2
April 21, 2015

1. Inside a conventional electric oven, heat is transferred by radiation from the heating element to the food being cooked. Radiation is a transfer of energy that does not require direct contact because waves of electromagnetic energy are able to travel rapidly through space until they strike matter and are absorbed. This results in molecules in the matter rapidly vibrating and the temperature of the matter to increase. When you first turn on either heating element inside an oven, the color of element first remains unchanged then gradually begins to glow and turns red and eventually an orange or yellow color. The element is becoming hotter simultaneously with the color progression. As the temperature of the heating element increases, the color of the glow continues to change. We have learned from the PhET simulation that the color of the visible wavelength is dependent on temperature. The higher that the temperature of the heating element becomes, the more kinetic energy it has. The wavelength will be smaller as the heating element gains more heat. This is why we see the color change from red to orange to yellow. We see the red wavelength first because this is when the heating element of the oven first begins to increase in temperature. The red wavelength is the longest and has the lowest kinetic energy. As the heating element gains heat, we can witness the color progression from red to orange to yellow due to an increase in kinetic energy and therefore smaller wavelengths of visible light.

2. Heat can by transferred by three mechanisms; conduction, convection, and radiation. The different methods of cooking such as baking and broiling involve different forms of heat transfer. Baking transfers heat energy primarily by the method of convection that is heat movement by the bulk movement of a fluid, in this case air. In the baking process, heat travels from the heating element of the oven to air by convection. The heated air then transfers heat to the metal baking container and to the top surface of the bread dough by convection. Baking bread in a metal container is cooking by conduction because there is an exchange of thermal energy by direct contact between the container and the material being cooked. Heat travels through the container by conduction and is also transferred from the baking metal container to the baked bread dough inside the container by conduction. Baking also transfers some amount of heat by radiation from the heating element. When broiling a steak, the primary mechanism of heat transfer is radiation. Radiation transfers heat through waves of pure energy, not through matter so it does not require a medium between the heat source and the food. The broil element of the oven transfers heat by emitting energy waves to the steak being cooked. During the broiling process, heat is also transferred by conduction from the metal sheet to the steak. Some heat will be moved by convection of air as well, but radiation plays the most important role in broiling.

3. Baking cookies on a flat metal tray in the oven will often result in cookies that are burnt on the bottom. This is because heat is being transferred by conduction from the baking sheet to the underside of the cookies. The bottom of the cookies is the only area in direct contact with the baking sheet so the bottoms often burn before heat is transferred through the entire cookie and cooks the tops. A cookie tray with two layers of metal separated by a narrow air gap will help prevent the cookies from burning on the bottoms and cook them just right throughout. The layer of air built into the cookie sheet will trap air in it, making the sheet less vulnerable to the lower heating element of the oven. This type of cookie sheet will take longer to heat up than a simple metal tray, so the risk of burning the cookies is greatly reduced. The air gap will help reduce the amount of heat transferred to the cookie sheet and therefore the cookie bottoms by conduction. The cookies will be baked more evenly as a result because the design of the cookie sheet allows for air to circulate and hot spots to be reduced.

4. When boiling water in a traditional teakettle, the water is heated by conduction. Heat is flowing from the burner to the teakettle by the collision of molecules where the two are in direct contact. The teakettle in turn transfers heat to the water inside. In a microwave oven, heat is transferred primarily by radiation, which causes the water molecules to vibrate. The rapid vibrations of the water molecules will eventually cause the water to boil as the molecules bump into each other and produce heat. The water being heated in the microwave comes to a boil faster because the microwave uses radiation and simultaneously excites the water molecules. This results in cooking more quickly and evenly than using a teakettle where the water is not being heated directly. The teakettle method is slower because first the teakettle gains heat energy by conduction and then heat energy is transferred by conduction from the kettle to the water.

5. a) Yes, a chemical reaction is occurring. Two substances, Bondo and the hardening agent, are being mixed and a new substance is formed as a result. The physical changes of the two original substances to form a new substance are evidence of a chemical reaction. Bondo started as a sticky liquid, but after mixing with the hardening agent an entirely new solid substance was formed from the chemical reaction. This is evidence that a chemical reaction has occurred because we are mixing two things and seeing the properties change as a result. On a molecular level, we know that bonds must be breaking and new bonds forming.

b) If the paste was warmer to touch as it was hardening then the chemical reaction must have released heat energy to its surroundings. Therefore, the chemical reaction that took place to create the paste was an exothermic process. The source of heat would be from the forming of bonds because when a bond forms, atoms are rearranged and energy is being released. The amount of energy released in bond making must have been greater than the amount of energy that was used when bonds in the reactants were broken. In a chemical reaction there is a tradeoff between the bonds broken and bonds formed. The net change in energy from this tradeoff determines whether the reaction is exothermic or endothermic. In this equation, the reactants (3 molecules of styrene) have 92.7x10^-19 Joules of energy.

The product side (polystyrene segment) has 96.9x10^-19 Joules of energy. The chemical reaction occurring with Bondo is exothermic because more energy is released in the products than the reactants. Therefore the energy for making bonds is greater than the energy for breaking. The heat source is the energy coming from making the bonds.

6. a) Car engines produce a lot of heat and therefore need cooling systems to protect them from overheating. The engine is powered by combustion, which takes place when fuel reacts with oxygen to produce heat. The engine will be producing heat whenever it is running, but the radiator protects the engine from overheating. You fill the radiator with the special coolant solution that is circulated through metal pipes attaching to the engine and it is heated there. The heated coolant solution then circulates back through the radiator where it loses heat to its surroundings. The radiator is able to effectively cool the solution by transferring heat from the solution to the air. Radiators use the heat transfer mechanism of convection because the hot coolant solution is passing through the metal pipes and simultaneously forcing air through the pipes. The air then moves through the honeycomb structure of the radiator and convection removes heat from the coolant solution. This aggregate motion of air, along with the presence of temperature differences, contributes to heat transfer from high to low temperature areas. The cooled coolant moves back to the engine and the cycle continues to keep the engine from overheating. The radiator is normally placed at the very front of the engine compartment because this allows for sufficient airflow from the forward movement of the automobile. This airflow is extremely important because it allows for the convection process to take place and the radiator to effectively cool the engine.

b) One condition where the radiator might fail to protect the engine from overheating would be a situation where the air flow was blocked, such as if the radiator was not placed in the front of the automobile or if the front grill did not allow air to pass through it. The air stream through the radiator allows the radiator to work; therefore if the air stream were interrupted it would be problematic. When a vehicle moves forward, a sufficient airflow passes through the grill and is channeled through the radiator. If the radiator were placed somewhere else where it did not receive a constant stream of air or if the airflow was not able to pass through the grill then convection would not take place. This is because convection is the transfer of heat through the bulk movement of a fluid. Under a condition where the airflow through the radiator was insufficient, convection could not occur. This would result in the radiator failing to protect the engine and the engine would overheat. Without the presence of air flowing through the radiator, heat would not be transferred from the coolant solution and dispersed away from the engine in the form of hot air.

Another condition where the radiator might fail to protect the engine would be if air was trapped in the radiator and could not flow freely through the cooling system. There are multiple situations where air could be trapped including issues with the radiator such as a bad radiator cap or corrosion to the radiator. Any situation such as these where air was trapped inside the radiator would be problematic and result in the system failing to protect the engine. The radiator keeps the engine from overheating by transferring heat through convection. As long as the air is not trapped, and is able to move freely, it can efficiently transfer heat. When air becomes trapped it can no longer mix with a fluid of different temperature. Heat would not be transferred well as a result of the trapped air since convection currents would not be created. This is the same idea behind insulation for windows that my group in class read about and discussed. One method of insulation for windows was to use double pane windows to trap air between the panes and decrease heat transfer by convection. Trapped air is good for insulation of windows but would have negative effects on an automobile's radiator. The trapped air would not allow for the radiator to effectively cool the engine by convection, resulting in overheating of the engine.

7. a) I expect the temperature of the water and the temperature of the mercury to both be at room temperature. Since the two liquids were left sitting on a lab bench since yesterday, they would have turned to room temperature. This is because both liquids would have reached a thermal equilibrium with the room after sitting out for such a time. After pouring the water and mercury into the containers, I expect them to be at the same temperature. Both the liquids would have already been at room temperature so when they are poured into the containers they would already be at thermal equilibrium with each other.

b) I was having issues making a graph on the computer. I have attached an image of a hardcopy graph that I drew out on paper.

c) I do not agree with the statement that mercury will reach its final temperature before water. I do agree that mercury is a better conductor of heat than water is because it is a metal, but it is my understanding that this will not cause mercury to reach its final temperature more quickly. The mercury and water should reach their final temperature at the same time. The two liquids will be exchanging heat with each other, so as the warmer water loses heat the colder mercury will be gaining it and vice versa. The mercury and water should reach an equilibrium temperature at the same time as long is they are exchanging heat with each other. This transfer of heat demonstrates the zeroth law of thermodynamics, which states that two objects of different temperatures will transfer heat with one another until a thermal equilibrium is reached. Thermal equilibrium is where the objects are at the same temperature and there is no longer a heat transfer between them.

d) The final temperature will be closer to the initial temperature of water due to the high specific heat of water. Specific heat is the amount of heat that is required to raise a certain mass 1 degree Celsius. Water has a much higher specific heat when compared to the specific heat of metals such as mercury. Based on the much higher specific heat, the total energy required to increase the temperature of water is much larger than the total energy required to raise the temperature of mercury. Therefore resulting in a final temperature that is closer to the initial temperature of water, since mercury does not require as great amount of energy per unit mass to increase its temperature 1 degree Celsius.

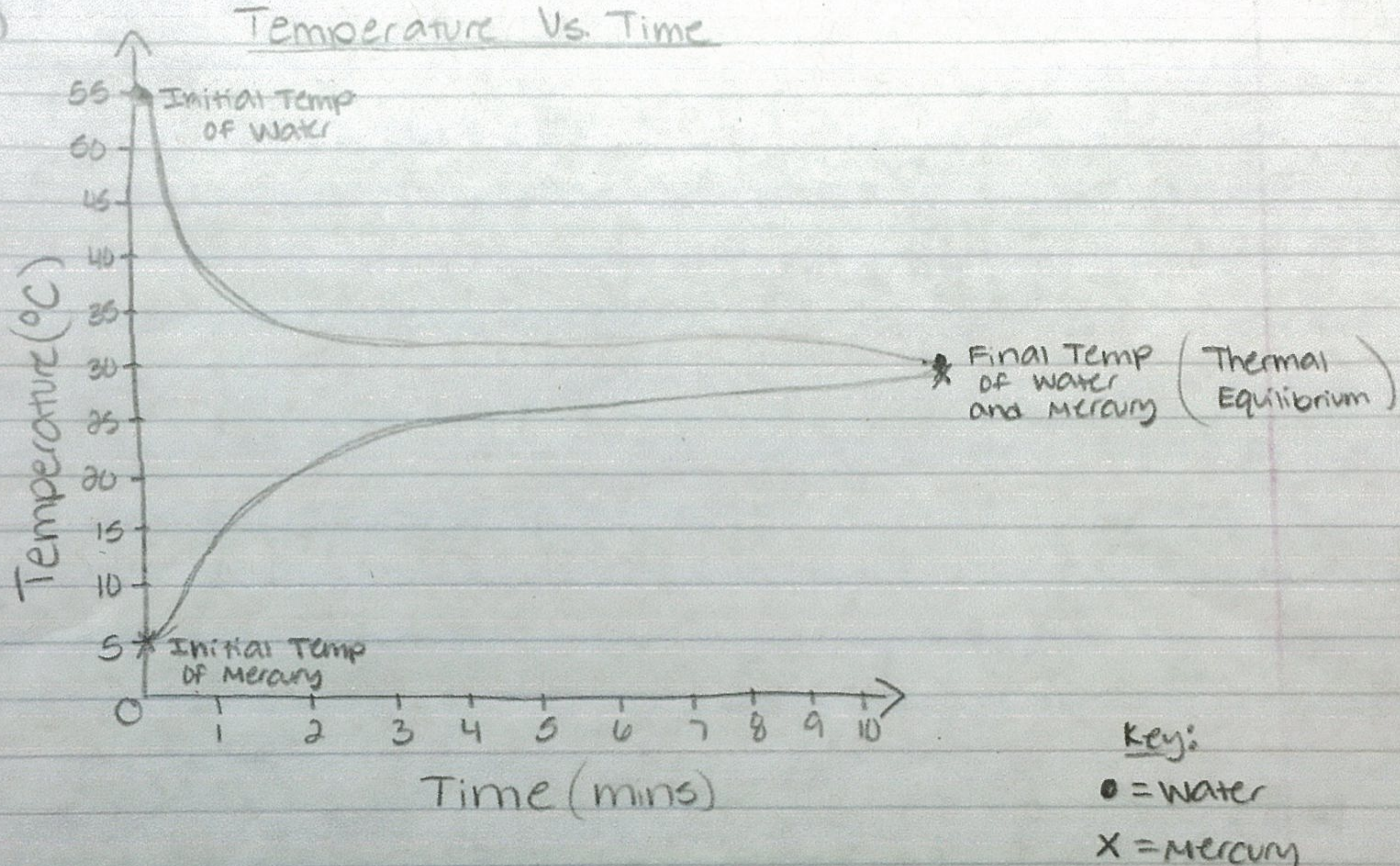
8. An unheated waterbed would be very uncomfortable for sleepers because the sleeper would be losing heat and feel cold as a result. Without a heater, the

water inside of the mattress would be cold. The cold water would draw heat from the sleeper's body. When there is a temperature gradient such as that between the sleeper and the waterbed, thermal energy would be transferred from the higher temperature sleeper to the lower temperature waterbed. This transfer of energy occurs through the collisions between molecules, a process known as conduction. With a heater placed in a corner of the waterbed, warm water would move through the mattress by conduction. The waterbed would be unbearably cold for most sleepers without the heater as it would be absorbing heat from their body.

C37

CHEM 444 A Fire and Ice
Exam 2

7 b)



EXAM 2

1. In a conventional electric oven the heat comes from an electrical outlet and is sent along a wire, typically made of copper or another highly conductive metal, which runs through the center of the "heating element". A metal layer encapsulates the copper wire. Copper is a very good conductor of heat, so as electric energy is supplied to the wire, the wire uses conduction to heat the metal sheath, which then gives off heat into the oven through radiation. Many ovens have a convection fan as a feature to circulate the heat evenly. As for the color change when the metal increases in temperature, this is due to thermochromic properties. As metals get hotter they change colors because they gain more energy. As more and more energy is gain, the molecules move around more and become unstable, and their electrons absorb for a short time some of that energy and release it in the form of light energy known as photons. The degree of light energy will determine the color of the metal, starting with red, and going to orange then sometimes yellow as heat increases. The technical term for converting heat energy into light energy is called incandescence.

2. Baking and broiling are two different ways in which to cook foods, with the main difference being the way in which they use heat. For example, if you wanted to cook a steak you would use the top heating element on to broil it. Broiling involves exposing the steak to direct heat on a broiling pan, similar to if you were to grill the steak. The broiling pan itself looks similar to the miracle thaw we used in class, in which there are diagonal grooves for air to get under the steak and cook it on the bottom as well, although it doesn't get the same char as the top part being exposed to direct heat will. Heat beats down on the steak from above through infrared radiation and usually reaches a much higher temperature (over 500 degrees Fahrenheit), which quickly sears the top of the steak in only a few minutes. On the other hand, if you wanted to make bread, you would turn the bottom heating element on to bake it. Baking involves exposing the bread dough in a deep metal pan, to hot air all around it. The pan is important because it surrounds the bread except for the top, and it allows the bread to cook from the outside in through conduction. The heat while baking is usually at a lower temperature, from around 200-400 degrees Fahrenheit, and it takes a longer time to cook than broiling does. The metal pan absorbs heat from the oven, and through conduction heats the bread dough on the inside of the pan, and continues in as a ripple effect until the middle of the bread is cooked. That is why when you check food in the oven you stick a toothpick in the middle, because that is the last part to finish cooking. Both broiling and baking are effective ways of cooking foods, but they use heat differently to do so.

3. Good bakers know not to use cookie sheets that are only a single layer of metal because it will burn their cookies. They know this because the bottom of the cookies is being heated directly through conduction to the pan, and the top of the cookies are being cooked by the circulating oven air, which is not as direct, causing the top to not cook as fast as the bottom. Double layer baking sheets are the solution for this because they have two layers of metal with a permanent air pocket in the middle. This pocket is critical because it allows the air inside it to rise to the same temperature

as the air exposed to the top of the cookies, letting both the top and bottom cook at the same rate. This eliminates the bottom of the cookies having to experience direct conduction to the pan, which can often get hotter than the baker wants it to be. The double layer pan allows for convection to cook the cookies evenly and eliminates burning.

4. Boiling water to make tea in a microwave uses infrared radiation and causes the water to boil in about 2 minutes, which is much faster than on the stove. This is because it provides heat from all angles, speeding up the process of convection in the water. As water begins to boil, the warm air on the bottom rises, and is replaced by cold water on the bottom and continues to cycle. This cycle happens a lot faster in the microwave than on the stove, which causes the water to boil faster. On the stove, the water is purely exposed to conduction, and is only heated on the bottom. This results in boiling taking up to 10 minutes because convection cannot occur as fast.

5.

a. Yes there is an exothermic reaction going on here. This is because the physical properties from the reactants to product have changed, from a liquid to solid state for example. Also, bonds of reactants are broken and formed again into a new substance, so there are new chemical properties as well.
b. The source of heat comes from the fact that the products yield more energy than the reactants, thus making it an exothermic reaction. The bonds that are formed produce more energy than the bonds used when breaking. In order to prove this, the energy for the reactants and products can be calculated by adding up the energy used to break the bonds of the reactants, and then the energy gained from the new bonds formed.
   i. Quantitative Argument:

reactants

$$\text{H-C } 6.9 \times 9 = 62.1 \quad + \quad \text{C=C } 10.2 \times 3 = 30.6 \quad = \boxed{92.7} \times 10^{-19}\,\text{J}$$

products

$$\text{H-C } 6.9 \times 9 = 62.1 \quad + \quad \text{C-C } 5.8 \times 5 = 29 \quad + \quad \text{C-C } 5.8 \times 2 = 11.6 \quad = \boxed{102.7} \times 10^{-19}\,\text{J}$$

6.

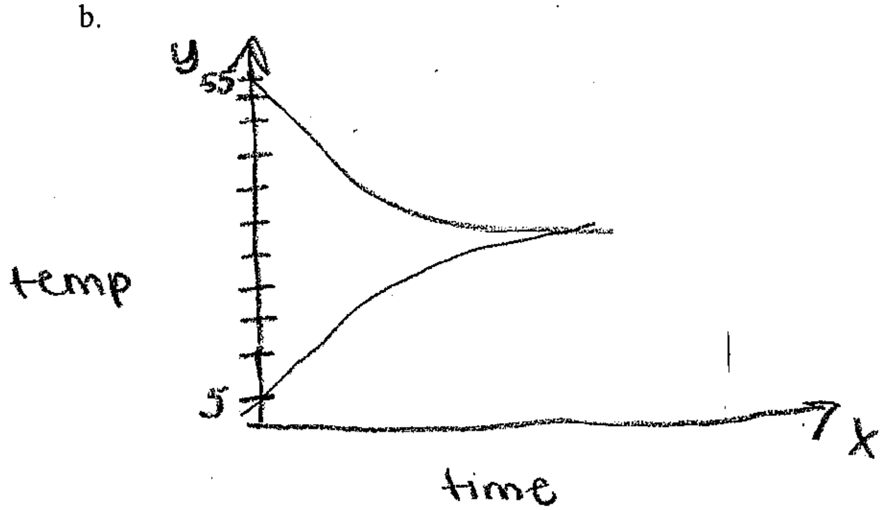
a. The radiator protects the engine from overheating because the coolant is distributed into the engine, where it absorbs heat from the engine and it gives off that heat to the metal of the radiator pipe. Once brought back to the bottom of the radiator again, the air that is flowing through the honeycomb structure of the radiator then cools it off. The cycle is able to continue again and again. Radiators are designed for the air to be able to flow all around the pipes to absorb the heat energy and take it away from the engine preventing it from overheating.

b. Two instances in which this system may fail to protect the engine would be if there is a leak in the coolant, or if the air outside it too hot. If there is a leak in a metal pipe and the coolant is able to get out, there will be no way for the heat from the engine to be absorbed, thus causing it to overheat. If the air outside is too hot, when the air flows over the radiator pipes it will not absorb any more heat, and that hot pipe and coolant will not be able to release heat from the system, thus bringing hot air into the engine, causing it to again, overheat.

7.

a. Just before pouring the two liquids into the containers I would expect the temperatures to be exactly the same of both liquids. I would expect this because they had been sitting out for a whole day and would have enough time to reach a thermal equilibrium with the room temperature air. I could understand if they had only been sitting there for a few minutes that they would be different temperatures, but not for a whole day.

b.




c. I disagree with this student's statement only because the temperatures of the two liquids were altered from their original temperature. If they had not been altered I would have agreed with the statement. I disagree because the ability of mercury to be a heat conductor is affected when it is at a cold temperature of 5 degrees Celsius. Mercury has more molecules per unit than water does, but if at a low temperature like that, the total energy of the system would have to be divided up that much more among them due to the first law of thermodynamics the conservation of energy. Because of this each particle would have less energy, and its heat conductive properties would not affect its speed of reaching a final temperature.

d. The final temperature would result around 40 degrees Celsius, which is closer to the temperature of water because of the greater amount of particles in the molecule of mercury than in water. Since the energy is dispersed onto more particles, a small change in energy will affect more mercury particles than water particles. This means that there may be twice as many mercury particles for example, but they only have half the amount of energy. As the temperature of the mercury increases, more and more particles are affected, and there will be a greater increase in the number of particles affected opposed to water. I believe that as more and more molecules are affected the temperature of mercury is able to increase more quickly because its particles have more energy, and aren't at such a low energy state, and with more of them, I believe that is why the temperature will be closer to water.

8. Unheated water-beds can be very uncomfortable for sleepers. This is because in a regular bed, when you lay down you heat up the mattress, and that area you heat up through conduction stays in the same spot and you are comfortable and you don't lose a lot of heat energy. In a normal waterbed the heat is being circulated in that same way through the whole bed so you do not have to continue to lose body heat to the bed. If the bed were unheated, you would constantly lose body heat do to the movement of the water all around and constant replacement of cold water under where you are sleeping. This would be very uncomfortable because you would always be cold.

H22

H22

CHEM 444A H01

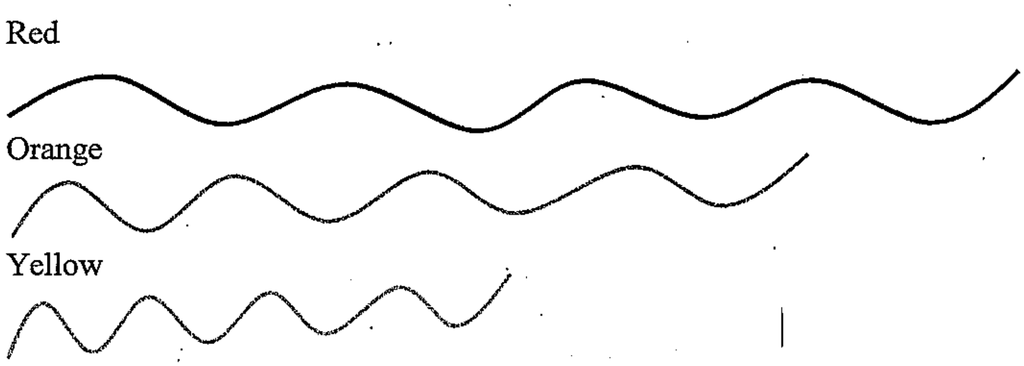
Professor Bauer

24 April 2016

Exam 2

1.) As the heating element in a conventional electric oven heats up its color will change from black or gray to a yellowish color. When the temperature increases the intensity of the light increases. Also, as the temperature increases the wavelengths shorten, which is why there is a progression from its original color to colors like yellow and orange and then eventually to blue. Visible light is categorized by color determined by wavelengths. Therefore as the element heats up it radiates more heat resulting in visible light with progressively shorter wavelengths. This is why a "blue flame" is hotter than an "orange flame". The heating element is radiating waves in the form of the heat transfer radiation. As the element's temperature increases the waves it radiates have progressively shorter wavelengths resulting in the changing of colors.

(The following are not to scale.)




As can be seen, the wavelengths decrease as the colors move from red to yellow. Higher temperatures radiate waves with smaller wavelengths which is why we see the element as different colors, determined by its temperature. This relates directly to our experiment using the Phet simulation. We saw that the colors changed as the intensity (temperature) of the sun increased. These changes are directly attributed to which visible light colors shows in relation to the corresponding temperature and wavelength. Although, the element is increasing the temperature of the air in the oven, making it less dense. This decrease in density alters the speed at which light travels. This relates directly to the color appearance of the sun. The hotter parts of the sun appear a yellowish color whereas cooler parts would appear red. This is why when we increased the intensity of the sun in the simulator the color of the present visible light changed. I related my answer to the graph of visible light which illustrated colors with decreasing wavelengths as intensity or heat increased (Phet).

2.) There is a big difference between baking and broiling. Baking occurs from the bottom element and heat is transferred by convection. There is some heat transfer by conduction to the food since the convection heats the pan. The pan then transfers heat to the food by conduction. The baking element heats the surrounding air. The heated air becomes less dense and rises transferring heat to the food by convection. Broiling is performed using the upper element and transfers heat through radiation. When baking the bottom element preheats the air in the oven to the desired temperature. Once the oven has reached the temperature set by the baker the bottom element will shut off. Therefore there won't be any heat transfer by radiation, as long as the internal oven temperature doesn't drop. This contrasts to broiling because the upper element only turns on when broiling and it stays on for the duration. Heat is transferred to the material being cooked by radiation, giving it a "crispier" texture. In conclusion heat is transferred to the material being cooked by convection when using the bottom baking element and heat is transferred by radiation (infrared) to the material being cooked when using the upper element for broiling. To bake bread you use a "deep" pan to allot for the bread rising. To cook steak you use a metal sheet since the steak will release juices but not rise like the bread. The baking by convection allows the bread to bake throughout allowing it to rise. Broiling and banking are similar in the fact that the initial heat transfer is caused by the element radiating heat. Even though heat is transferred to the food by convection, the element radiates heat while the oven is preheating. This radiation of heat from the element causes the air to become heated which will eventually cook the food.

3.) Regular cookie trays don't have a gap of air between the two pieces of metal resulting in the bottom of the cookies burning. This is because as the bottom the warm air in the oven heats the tray rapidly since it is a good conductor of heat. Heat is transferred to the tray by convection and the tray transfers heat to the cookies by conduction. The top of the cookies are cooked by the hot air within the oven. Therefore since the tray gets hot much quicker it burns the bottom of the cookies while the air (convection) is still cooking the tops of the cookies. A tray with a "narrow air gap between the two layers of metal" doesn't burn the bottom of the cookies as the trapped air reduces the conductivity of the tray. Air isn't a very good conductor of heat. Therefore when the heated air heats the bottom layer the trapped air prevents great conduction from the bottom layer to the top layer, thereby slowing the heating of the tray allowing the cookies to cook just right all the way through. This is similar to the shell of the ISS. Each layer of the ISS was divided by a non-conductive material to prevent the shell from overheating. The air between the layers acts the same way. Heat will be transferred to the bottom layer by convection (convection baking ovens). The transfer to the cookies is much slower now that there is a subdividing layer of air, whereas on a traditional tray the bottom of the cookie would become hot very fast causing it to burn while the rest of the cookie was cooking. By reducing the conductivity of the tray, heat transfer to the bottom of the cookies is slower, preventing them from burning.

4.) Water can be brought to a boil much quicker in a microwave than on a regular electric heating element on a stove. On a stove water is heated through conduction. The heat is transferred from the element to the kettle and then from the kettle to the water. This process takes longer than the heating of water in a microwave through radiation. In a microwave the water is heated through radiation, causing the water molecules to speed up quickly. On a stove top the heat transfer through conduction takes much longer since the kettle has to be heated and then the kettle heats the water. The microwave is faster because the heat is radiated directly to the food (water). Whereas in a kettle the entire apparatus in contact is heated. The heat transfer by radiation accelerates the water molecules directly, allowing there temperature to rise quickly. The temperature of the water increases when its molecules speed up. Therefore radiation by micro-waves speeds up the water molecules very quickly. On a stove the element conducts heat to the kettle. So the fast moving molecules of the element collide with those of the kettle causing the kettle's molecules to speed up. Once the kettle's molecules speed up they begin to collide with water molecules causing there molecular speed to increase as well. This process takes much longer than radiation heating water molecules directly. This can be compared to when we heated water in the microwave. The air temperature in the microwave didn't rise nearly as much as the water's temperature, proving that heat wasn't being transferred by convection. Heat transfer by radiation has proven to be much quicker than heat transfer using a traditional stovetop.

5.

a.) When styrene is mixed with a hardening agent it becomes polystyrene which is a hard substance used to cover holes on a car body. When the mixture of "liquid Bondo" and the hardening agent becomes harder the observation is that the temperature increases. An increase in temperature is a characteristic or signal that a chemical reaction is occurring. There is also an obvious change in the physical state of the mixture (hardening). Although the hardening aspect doesn't necessarily portray that a chemical reaction is occurring, the fact that the temperature is increasing as well suggests that there is a reaction occurring. From the molecular diagrams given we can see that bonds are broken (double bonds) and made to form the final polystyrene product. The reaction is between the styrene (shown) and the hardening agent to form polystyrene (also shown). The polystyrene forms though the breaking and creating of bonds which is synonymous with a chemical reaction. All of these events can be seen by comparing the diagram of the styrene (reactant) and the polystyrene (product). We know there is a chemical reaction occurring since substances are reacting causing bonds to break and resulting in new bonds being formed. This description coincides with a chemical reaction which is evidence that a reaction is in fact occurring.

b.) Since the "Bondo" feels warmer the reaction is probably exothermic. In an exothermic reaction the products require less energy than the reactants resulting in the release of heat from the system. The heat which can be felt is coming from the reactants. The reactants in this case are the styrene molecules and the hardening agent. Reactants are combined to form products. Energy is pulled from those reactants and released when the product is formed. This question is similar to that of the experiments we performed with Ben regarding endothermic and exothermic reactions. To see the energy transfer or where the heat is coming from we could track the change in temperature throughout the reaction. For example if the reactant (styrene) is 22$^0$C prior to being combined with the other reactant ("hardening agent"), then the product which is polystyrene will be warmer possibly around 26$^0$C. Therefore the product will definitely have a higher temperature than the individual reactants since it's an exothermic reaction and the product requires less energy than the reactants. Since the products require less energy than the reactants energy (heat) is released. The quantitative portion of this question relates to the amount of energy in versus the amount of energy out. As shown, three molecules of styrene are used to produce polystyrene. By substituting the correct amount of energy for each bond in the reactants (x10^-19 Joules) we can compare the amount of energy in (bond breaking) and the amount of energy out (bond formation). Each styrene molecule absorbs 10.2 x 10^-19 Joules. Since there are three styrene molecules the gross energy in is (10.2)(3)=30.6x10^-19 Joules. This isn't the total energy in since the "hardening agent" which is the other reactant hasn't been accounted for. This amount represents the amount of energy in needed to break the bonds for the chemical reaction. The total energy out for three styrene molecules is 40.6x10^-19 Joules. This represents the amount of energy released to form the new bonds in the reaction. By calculating the energy associated with each set of bonds (that changed) I can determine where the heat is coming from and whether the reaction is endothermic or exothermic. A single bond between H and C is 6.9J. A single bond between C and C is 5.8J. A double bond between C and C is 10.2J. Using these energy amounts and the provided molecular structures of the reactants and products I was able to determine that the reaction is exothermic because energy out is greater than energy in. This means that more bonds are made than are broken (not necessarily numerically, but quantitatively as it relates to energy transfer). This causes a release of energy, and thereby the material feeling warmer.

6.

a.) Radiators are an apparatus used in automobiles to prevent the engines from overheating. The radiator is located at the front on the automobile behind the grill assembly. This allows air to freely move into the radiator when the car is traveling down the road. Engines produce heat while they are running, therefore something must be done to prevent them from overheating. A radiator is a completely metal, usually aluminum, structure that is filled with a coolant. This coolant is usually "anti-freeze" radiator fluid. Water can be used but it runs the risk of freezing or evaporating, therefore anti-freeze is used because of its low freezing point and high boiling point. The fluid in the radiator is circulated throughout the engine block to cool it. As the automobile travels down the road the air which hits the front of the radiator penetrates the honeycomb structure and cools the fluid within. This fluid then runs back through the motor. The heat from the motor is absorbed by the fluid. The heated fluid then runs back into the radiator where the cool wind generated by the car moving cools the fluid. The metal radiator is also a good conductor of heat, allowing heat to travel from the liquid to the metal. As heat is pulled from the liquid its temperature decreases. This is similar to the radiator cooling system on the ISS that we discussed in one of our class discussions. The heat from the motor is absorbed by the coolant, until it circulates back to the radiator where it is released. The radiator and the surrounding air can feel warm as the result of the absorption of heat from the heated coolant. This process continues as long as the motor is running to prevent overheating. There is also usually a fan attached to the radiator which generates even more air flow to further cool the circulating coolant. Overall, the fluid runs through the motor absorbs its heat and returns to the bottom of the radiator. Once the fluid is cooled it is recirculated through the motor via the top tube. This process is continuous to prevent overheating.

b.) There are certain situations where the radiator can fail to prevent the engine from overheating. If an automobile is left idling, usually on a hot day, the circulating coolant won't be cooled since there is no air flow reaching the radiator. Since there is no "on-coming" air interacting with the radiator the coolant won't be cooled. Therefore hot coolant will continuously circulate throughout the engine bock until the motor overheats. Therefore the coolant would keep absorbing heat from the motor until it reached its boiling point resulting in the motor overheating. Another situation that would result in the radiator failing to properly cool the motor is if the automobile is moving at extremely slow speeds on a warm day. The radiator would not function properly for the same reasons as if the car was left idling. There wouldn't be enough air generated to cool the circulated coolant. Each radiator has a pump which is responsible for circulating the coolant throughout the engine block and back to the radiator. If this pump fails the coolant will "sit" in the block and absorb heat. The coolant will continuously absorb heat as it won't be able to return to the radiator to cool by releasing that absorbed heat. The engine will overheat in this situation as well. Some people, such as amateur race car drivers use water as a coolant in there radiators. Water has a relatively low boiling point forcing these drivers to refill there radiators often. Once the engine reaches 212$^0$F or 100$^0$C the water will begin to evaporate. Therefore is the coolant isn't refilled it will eventually run out and result in the engine overheating. Another similar condition to this that would cause the radiator to fail is a low coolant level. Automobiles in today's world will alert the driver if the coolant level is getting low. This is because a low coolant level will result in the engine overheating. If there isn't a substantial amount of coolant the engine will overheat because when the coolant is circulated into the motor it absorbs heat. The coolant is then circulated back to the radiator to be cooled, but since there is very little amount of coolant available it is circulated back into the motor before it has time to fully cool (release its heat). Over time the coolant temperature will gradually rise until it evaporates and the engine overheats. A large enough amount of coolant is needed to allow heat to be released before the coolant is circulated back into the motor to absorb more heat.

7.

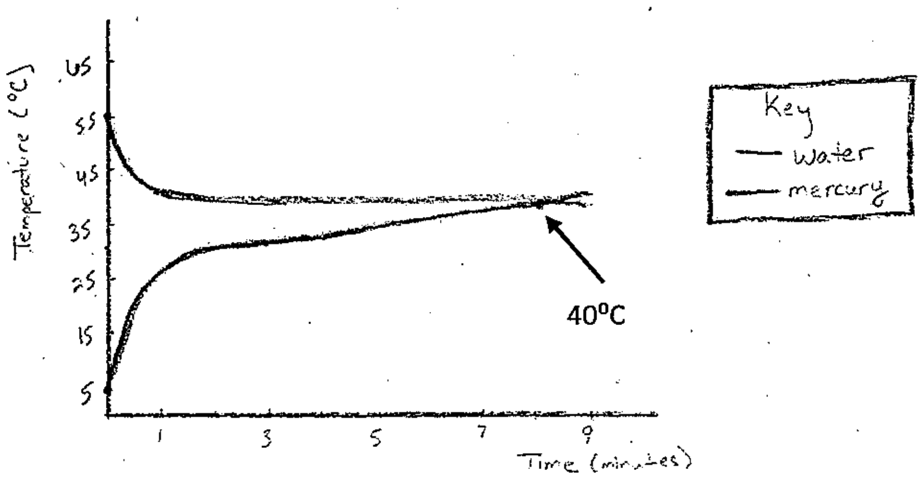
a.) Assuming that the water and mercury had been sitting on the lab bench for several hours I would safely assume that the temperature of the water and the mercury just after pouring them into the container would be room temperature or just below it. Eventually while the water and mercury were sitting on the lab bench the room temperature air from the lab would cause the temperature of each substance to reach thermal equilibrium with it. Since the container is thermally insulated from the rest of the lab its internal temperature could possibly be slightly colder than room temperature. Therefore when the substances are poured in there temperature may drop extremely slightly after being in the container for only a second. These assumptions were all made assuming the lab was at normal room temperature of around 68$^0$F. Therefore the liquids should be close to the same temperature. Just after pouring the liquids into the container I would expect both of their temperatures to be the same as that of the lab.

7.

b.)

Temperature vs. Time (Water & Mercury)

Reaching Thermal Equilibrium



b.) When graphing the temperature vs. time curves for water and mercury I made the assumption that they were both present in the same quantities. Although, differences in properties between the two substances would prevent the final temperature from being 30$^{o}$C or halfway between the two initial temperatures.

c.) I disagree with that statement. Thermal equilibrium, or when no heat energy is being exchanged as a result of the substances being at the same temperature, will be achieved at the same time for both substances. The final temperature is the temperature that both substances will eventually be at. Therefore there is a transfer of heat energy from the hot substance to the cold substance until the final temperature is reached. Both substances will reach the final temperature at the same time. The final temperature of the substances can be achieved when there is no longer a transfer of energy between them. Even though the divider is a "modest conductor" it will still transfer heat energy between the two substances. Therefore both substances should reach their final temperatures or stop changing temperature at the same time, or when they are both the same temperature.

d.) Even though the substances are present in the same quantities the differences in densities causes the final temperature to be slightly closer to the water's initial temperature. Mercury has a slightly larger amount of molecules per unit of volume than water. Therefore mercury has a greater density. From class experiments and discussions I know that when heat is transferred to a substance the molecules begin to move faster and collide. With each collision between molecules there is a transfer of heat energy. Since mercury has a greater density, less energy has to be transferred to raise its temperature since there will be a greater number of collisions. Therefore since less energy has to be transferred to raise the mercury's temperature the water will transfer less energy. If the substances were the same the molecules of one would speed up as much as the others slow down. Since the molecules of mercury are packed tighter they will speed up more than the water molecules slow down (with energy being conserved), causing the mercury's temperature to rise more than the water cools. In other words, a smaller energy transfer will cause a greater number of collisions and therefore an increased temperature. This is why the final temperature is slightly closer to the water's initial temperature.

8.) Water beds that are unheated would be very uncomfortable for sleepers. The water has a much lower temperature than the human body. Through conduction the heat will transfer from the sleeper (hot) to the water (cold). Therefore the water will draw heat form the sleeper, making them feel cold throughout the night. The cold water would continually draw heat from the sleeper until they were both at the same temperature. Thermal equilibrium probably wouldn't be achieved over the duration of one night because of the large volume of water, so the sleeper would gradually get colder. This type of heat transfer would be conduction since the two substances in contact (the structure of the bed being a divider) would transfer heat directly. Water beds must have water heater to allow for comfortable sleeping. The human body won't radiate enough heat or conduct enough heat to the water to heat it to a comfortable level. Circulating water throughout the inside of the bed would help transfer energy throughout the water and raise it temperature. The circulation would also increase particle activity in turn increasing its temperature.

Exam 2

1. These are different levels of light: ultraviolet, visible light, and Infrared. As the elements begin to warm heat is conducted to the air and the temperature inside the oven increases. As the elements continue to heat, they eventually reach a heat that is a part of the visible light spectrum. The first heat that produces a color, produces red. As the elements continue to increase in temperature the color of the element moves along visible light spectrum, from red to orange to yellow. The elements show color because all objects emit electromagnetic radiation; however it is only as the object heats that the wavelengths emitted become shorter and become a part of the visible light spectrum.

2. As the bread bakes heat is transferred up and through the pan to the bread. The pan allows for good conduction cooking the bread through the bottom and the sides and allowing the bread to rise. Broiling allows more heat to transfer through the top of the steak and around. The sheet allows air travel beneath the steak, thus the steak can cook evenly and the bottom does not burn before the middle is cooked.

3. If there is only one sheet of metal the heat transfers directly up and the bottom of the cookie receives the most heat energy. With the air gap, air provides some insulation and slows the conduction of heat energy through to the cookie. Thus, the cookie requires more time to cook allowing more heat to enter throughout and around the cookie, and the cookie tops can then get "done"

4. Microwaves heat through radiation, while stoves heat through conduction. Microwaves transfer energy directly to the water at the center. Conduction involves first the heating of the burner, which then transfers heat to the kettle which transfers the heat energy to the water molecules.
The direct transfer of energy through radiation is much faster than the process of conduction that occurs on a stove.

5. a. Yes. A chemical reaction is occurring because there is a change in the composition of the substances. Properties change in the process, bonds are broken and formed, and styrene becomes a new substance - polystyrene.

b. As the styrene becomes polystyrene bonds are first broken and energy is taken from the surroundings. C=C bonds break and C-C bonds are formed attaching the molecules. It requires $10.2 \times 10^{-19}$ J to break a C=C bond, and the forming of a C-C bond releases $5.8 \times 10^{-19}$ J. The fact that the reaction is exothermic is not apparent until considered for more than 5 styrene molecules. This is due to the fact that attaching the molecules to form the products results in one less bond. The C-C bond releases more than ½ the energy gained to break C=C. At 5 molecules (& greater) the net difference becomes such that more energy is released than gained.

$5 \times 10.2 = 51$ gained
$9 \times 5.8 = 52.2$ released
$\boxed{1.2 \times 10^{-19}}$ released

6. a. The radiator prevents the engine from overheating because the solution and air inside the radiator accept heat from the engine. The molecules of the solution then transfer the heat to the metal and out through the atmosphere as it circulates. Also, the air moving through the honeycomb accepts the transfer of energy, and thus the air molecules move energy out of the system. When the coolant returns to the bottom of the radiator it has released heat and can once again accept heat energy

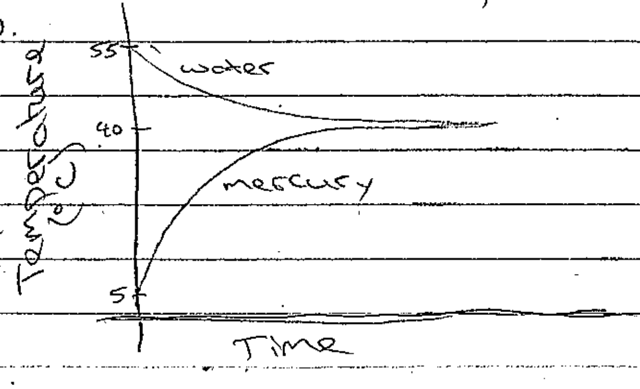
from the engine, thus preventing the engine from overheating.

b. If the radiator becomes dusty, and the honeycomb structure becomes clogged, then the lack of air circulation could result in a lack of sufficient cooling and the engine could overheat.
Also, if the environment is particularly hot surrounding the radiator then the engine could overheat because not enough heat energy is being transferred to the surrounding. Thus, the coolant remains hot and cannot accept as much heat from the engine.

7. a. I would expect the temperatures of the liquids to be room temperature, because they have been in the room for a whole day transferring heat between the molecules of their liquid and the environment, thus forming a relative equilibrium.

Water & Mercury

b.



c. Mercury as a liquid is also a better heat conductor with a conductivity of 8.21 W/m·K as opposed to water's 0.556 W/m·K thus I would expect mercury to transfer its heat energy more rapidly. However, the process of reaching an equilibrium is such that when an equilibrium is being reached both substances are reaching the temperature at approximately the same time. Mercury cannot reach the temperature before water, because if mercury has obtained the energy to reach the equilibrium then the remaining energy must be with the water molecules and thus the water molecules will have also reached the equilibrium temperature. (Perhaps the heat in the mercury is more evenly distributed because of the greater conductivity, however

d. Because mercury has more molecules per unit of volume this means the molecules of mercury are smaller. More energy is required to raise or drop the temperature of a water molecule than to change the temperature of a mercury molecule by the same amount. Thus, as energy is transferred from water to mercury molecules, less energy from the water molecules is required to raise mercury molecules' temperatures a greater amount.

Thermometers measure the average heat energy of molecules. Thus, even if the water molecules have not yet evenly distributed their energy, the thermometer read of the average will be at approximate equilibrium.)

J31

8. The human body maintains a relatively high temperature at homeostasis. When a body rests and becomes still it is not producing as much of its own energy and heat. Thus, if the environment is even slightly cooler than the body, the person soon finds themself in discomfort. The discomfort is caused as a result of the molecules of the cool bed conducting heat energy away from the skin of the body.

K29

CHEM 444
Test 2

1. When you turn on an electric oven an electric current is sent through the heating elements. The electric current is converted into thermal energy. All things are made up of atoms, including the heating elements. Atoms will vibrate as they become heated. As the electric current runs through the heating elements and is converted to thermal energy the atoms vibrate in response to the thermal energy. The vibration of atoms emits electromagnetic waves. The atoms will vibrate more intensely as thermal energy increases, which causes the atoms to emit higher frequency wavelengths. As temperatures increase the frequency of wavelengths becomes higher. Therefore, when an oven is gradually warming to the desired temperature the atoms are increasing in vibration and emitting higher frequency wavelengths as the temperature rises. The frequency of wavelengths determines color. The heating elements in the oven have a high enough temperature to emit wavelengths in the visible light range. These high frequency wavelengths are seen as red. If the temperature continues to rise then the color will become orange or yellow. The electric current is sent through the heating elements and converted to thermal energy. The thermal energy causes the atoms to start vibrating and emitting electromagnetic waves. The atoms are not vibrating enough to emit visible wavelengths when the oven is first turned on. That is why the heating elements appear unchanged at first. The vibration of atoms increases and higher frequency wavelengths are emitted as thermal energy continues to increase. The high frequency wavelengths make the heating elements glow red. If the electric current continues to flow through the heating element the temperature will become hotter, the frequencies will become even higher, and the heating elements will have an orange or yellow glow. The color of the wavelengths follows the pattern of ROYGBIV.

2. Baking food is achieved through the process of convection. Some radiation does occur, but it is limited. Convection is the transfer of heat through air or water. Heat transfer occurs through the air in the case of baking. The food item is placed in a pan and put on the oven rack. The pan does not have direct contact with the heating element so

conduction is not the mode of heat transfer. Convection is also the reason ovens are preheated. The air in the oven needs to be warmed to a constant temperature so the food is surrounded by the hot air. The heating element will turn off at points during the baking process to limit radiative heat. It will turn back on to keep the air temperature at the desired level. The air close to the heating element is warmed and rises to the top of the oven because hot air becomes less dense and rises. This hot air then pushes cooler air down towards the heating element where it can be warmed and then rise once it is hot air. This creates a circulation of air in the oven, which allows the food being baked to be surrounded by hot air. The food will be baked evenly through because of the circulation of air. The heated air that is moving through the circulation will penetrate the food, thus baking it.

Broiling food is achieved through radiation. Radiation is the transfer of heat through electromagnetic waves. Radiation does not require contact with an object, liquid, or water. The top heating element is used for broiling in an oven. The food is usually placed on the rack closest to the upper element so the electromagnetic waves can penetrate the material being cooked more easily. The atoms in the upper heating element are vibrating vigorously and penetrating the pan with heat waves. Unlike baking, the heating element will not turn off because radiation is desired. The wavelengths carry heat energy away from the heating element and to the material being cooked. The energy is absorbed and causes the temperature of the food to rise. The transfer of heat through radiation relies on the ability of the pan holding the food to absorb the heat energy. Dark or black metal sheets absorb heat energy from radiation very well. The cooler molecules in the metal sheet interact with the heat energy in the electromagnetic waves. Heat is transferred from the wavelengths to the molecules in the metal sheet. The molecules in the food can then absorb the heat from the molecules in the pan.

3. The air gap is the reason that the cookies will not burn on the bottom. Air is a very poor conductor, which means that it does not allow heat to easily pass through it. Air is then an insulator. Air is a good insulator because its molecules are so spread out. When air is heated the vibration of its molecules have less of an effect on each other. The air will prevent the heat from escaping quickly. The air gap between the cookie trays will delay

the heat energy from passing right to the cookies. This is similar to Styrofoam being a good insulator because it has air pockets. Air can slow down the transfer of heat.

4. Boiling water in a kettle on a stove-top is achieved through conduction and convection. The kettle has direct contact with the stove top, therefore conduction is the mode of heat transfer. The heat energy from the stove top is being transferred to the kettle. The molecules of the stove top are hotter than the molecules in the kettle. The cooler kettle molecules absorb the heat energy from the molecules in the stove top when they come in contact with each other. Conduction is the reason why the kettle will feel hot to the touch. Once the kettle has absorbed heat energy it will begin interacting with the water inside the kettle. The molecules in the kettle are now warmer than the water molecules. The molecules will interact and there is a transfer of heat from the molecules in the kettle to the water molecules. As the water molecules at the bottom of the kettle heat up they will spread out and become less dense. These water molecules will rise and push the colder molecules towards the bottom of the kettle. The colder molecules at the bottom will then be heated and rise. The circular movement of heat energy is created within the water. The heat energy is moving with the water, which means that heat is being transferred through convection.

   Water is boiled in the microwave through radiation. Microwaves are emitted into the food compartment and bounce back and forth off the walls of the microwave. The microwaves will transmit heat energy directly to the water. As the microwaves travel through the water they transfer heat energy to the cooler water molecules. The cooler water molecules absorb the heat energy and begin vibrating more rapidly, which increases the temperature of the water. Using a microwave to boil water is so much faster than using a stove top because the microwaves channel heat energy directly to the water molecules. Whereas, with a stove-top the molecules in the kettle are heated through conduction, pass their heat energy to the water molecules, and then convection occurs to transfer heat energy throughout the water.

5. Yes, there is a chemical reaction going on here. A chemical reaction occurs when substances, called reactants, interact and form new substances, called products. The

products are new substances because they have different molecular structures and have noticeably different characteristics than the reactants. In this example styrene is a liquid and once it undergoes a chemical reaction with a hardening agent it converts to a solid. Clearly, the characteristics of the reactant and product are different. The resulting solid also has a different molecular structure.

b. The source of the heat comes from the creation of bonds between the molecules of styrene. Energy must be absorbed to break bonds and energy is released to form bonds. In this chemical reaction $92.7 \times 10^{-19}$ J is gained in this reaction. Not including the ongoing chain of C atoms $91.1 \times 10^{-19}$ J is released from the reaction. This would suggest that more energy is gained than released. However, the paste was warmer to the touch. The reaction must be exothermic because heat was released by the reaction. This leads to assuming that the Carbon chain does continue, which would add on a varying amount of $5.8 \times 10^{-19}$ J to the energy released.

6. The coolant or water that is in the radiator circulates between the engine and the radiator through a pump. The coolant absorbs the heat from the engine as it flows through the passages in the engine. The coolant then carries the heat away from the engine and into the radiator. The coolant is cooled down by the air that passes through the honeycomb structure of the radiator. The air can enter the system through the grill in the front of the car. The heat from the coolant is absorbed by the air through convection and then released into the atmosphere. Evaporative cooling is also at play in this process. The heat from the engine would evaporate some of the water/coolant as it passes through the engine. This would result in the air in the engine cooling down.

b. Humidity would cause the evaporative cooling of the system to fail. Humidity would stop evaporative cooling because there is moisture in the air. Evaporative cooling works by turning water into its gaseous state or water vapor. If there is already a lot of moisture in the air then the water vapor will not be able to be released into the air. The air molecules are already saturated and cannot absorb any more water. This is why sweat does not evaporate off the body when it is humid outside. Another condition that would inhibit the system from cooling the engine is if the engine is running, but the car is stopped. Air cannot flow through the honeycomb structure of the radiator and thus cannot cool down the coolant before it returns to the engine. Fortunately, radiators come equipped with fans to blow air into the system so the engine does not over heat when the car is not in motion.

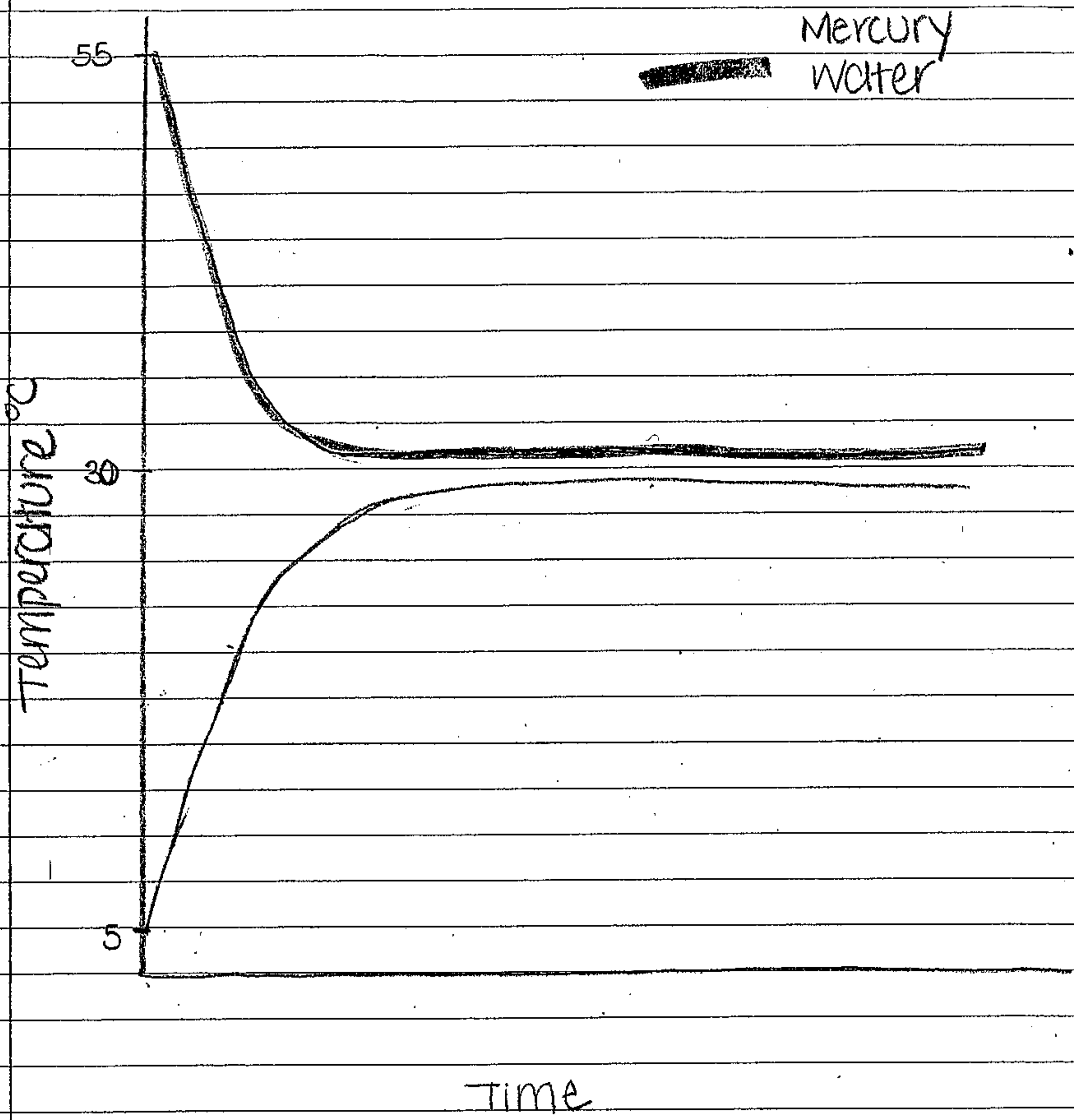
7. The water and mercury would both be at room temperature. They had been sitting out at a lab bench and were not heated or cooled. Therefore, both the water and mercury should be at room temperature. There is no reason why one would be hotter or cooler than the other unless one had been warmed or cooled. Neither Mercury nor water is naturally cold or hot in its liquid phase like liquid nitrogen so mercury and water should be room temperature.

   b. The water and mercury should reach a median temperature according to the law of thermodynamics. The temperature should be around 30 degrees Celsius.

   c. I do not agree with this statement. Water has a very high specific heat so it requires more energy input before its temperature will change. Mercury has a lower specific heat than water so it will reach its final temperature more quickly than water.

   d. The specific heat of water is larger than the specific heat of mercury. It will take water longer to drop in temperature. Mercury will quickly warm up and the two will meet thermal equilibrium.

8. Unheated water beds were uncomfortable for sleepers because the water would draw on the body heat of the sleeper. If the water in the waterbed is cooler than the body temperature of the sleeper than the sleeper's body and the water will want to gain thermal equilibrium. The sleeper's body is warmer so heat would flow from the body to the water in the waterbed. The waterbed would be sucking out the sleeper's body heat all night and make them cold and quite uncomfortable.


Mercury
Water
55
30
5
Temperature °C
Time

L18

Professor Bauer
Chem 444H
24 April 2015

Take Home Test Responses

1. When you turn on these elements in an electric oven, electricity runs through this metal rods, giving the molecules inside them energy. This energy is absorbed by the molecules in the rods, and these molecules begin to vibrate faster and faster, which causes the temperature of these rods to increase. Any air molecules directly touching these rods will collide with them and in turn some of the energy form the rod will be transferred to this molecule (conduction). As molecules near the rod heat up, they will rise because they are less dense and will be replaced by cooler air molecules, which results in a movement of air (convection). These kinds of heat transfers occur in order to reach a thermal equilibrium, however heat transfer takes time which is why some areas of the oven are hotter than others. However, the rod also gives off energy in the form of radiation in both the infrared and visible light spectra. When the element first starts to heat up, it looks unchanged. However, it will give off infrared radiation, which is then absorbed by the air molecules in the oven. As the element gains more and more energy, it begins to emit radiation on a higher energy wavelength, which is why the element turns red and then orange and yellow. Red is the closest wavelength to the infrared spectrum, so when it first reaches the energy state where it can emit visible light, this is the color we see. As it gets hotter and hotter it emits orange and then yellow light, because these are even higher energy wavelengths. While the element is red/orange/yellow though it still emits the infrared radiation as well, which continues to warm up the air inside the oven, as well as the sides of the oven. This is where this heat and light come from.

2. The difference between broiling and baking is that in broiling you are using mostly radiation to cook the meat, while in baking you are using mostly convection to bake the bread. Since the broiling element is on top, the air that it heats up which is close to it won't really cycle throughout the oven because it is already at the top, and is the least dense. This means that the primary source of energy for the meat comes from the infrared radiation given off by the broiling element as described in the previous question. This radiation travels from the element to the meat and is absorbed by the molecules in the meat, exciting them and increasing their temperature, which cooks the meat. In baking, the baking element on bottom yields a more convection-based effect, because it warms the air, which creates convection flowing throughout the oven. This warms the bread more gradually and less intensely than the broiling would, because the heat is transferred primarily through warm air molecules. It might be helpful to think of this with regards to our bodies. When we are out in the sun, the radiation from the sun can essentially cook our skin, sometimes causing sunburns. This sort of burn from radiation

is exactly what cooks the steak. However, if we were just sitting in a sauna or warm room where there is no sunlight, we would only sweat and couldn't get burned, because our body is simply warming up. This parallels how the bread is baked using the bottom element. This is because as the warm air from either the sauna or the oven comes into contact with our skin or the bread, its energy is transferred to the other substance from collisions, increasing the energy of that substance resulting in an increased temperature.

3. The difference in these results comes from the fact that conduction is a much more efficient method of heat transfer than convection. We discovered this in experiments involving the miracle thaw and a few other activities, because ice melted much faster when in contact with something than when in contact with mostly air. We also found that metal is a great conductor of heat, and that air is actually an insulator, meaning it is a very poor conductor of heat, which is why we use it to insulate our homes. This can be applied to this cookie baking issue because a simple metal tray will absorb heat very quickly and transfer it very quickly to anything in contact with it (the cookies). This would result in the bottom of the cookies cooking very fast, while the top of the cookies are only receiving heat from the air surrounding them through convection. This process occurs much more slowly than conduction, which is why the top cooks slower than the bottom. The double layered tray with a gap in between helps prevent the bottoms from burning because as previously mentioned, air is a poor conductor, so the layer of air between the layers of metal will keep the heat from being transferred so quickly. Furthermore, this layer of air allows for convection to actually take away some of the heat from the metal trays, warming the air more and keeping the tray from getting too hot. This would result in the bottoms of the cookies cooking slower than if it was just the one-layered tray, keeping them from burning while the tops cook.

4. When you use a teakettle on a stove top, the heat is transferred primarily through conduction. The heating element acquires energy (say electrical) and heats up because its molecules have more energy and are vibrating faster. As the stovetop heats up, the places where it is in contact with the teakettle are sites of conduction. This occurs because the molecules of the stovetop are colliding with the molecules of the teakettle giving their energy to the molecules of the teakettle in order to reach a thermal equilibrium. Since the teakettle is metal and metal is a great conductor of heat, the energy is transferred quickly from the metal kettle to the water in it through conduction again. The warm water in contact with the bottom and sides of the kettle will then rise, being replaced by cooler water, which will then warm up (again, convection). When using a microwave, heat is transferred through infrared radiation. The microwave emits electromagnetic radiation in the infrared spectrum, which is absorbed by the water in there causing the water molecules to move faster, increasing their temperature. The microwave is designed so that all most all of this energy is focused on whatever is being cooked, and the sides of

the microwave try to reflect the energy. Since all the energy is going towards the water molecules, this is why it heats up faster than on the stovetop. On the stovetop, energy may be lost in the form of heat to the surrounding air. This is because the air moves heat away from both the kettle itself and the stove through convection. This heat is energy that does not go towards the boiling of the water, which is why it takes longer to boil on the stove.

5. Yes, there is a chemical reaction going on here because the styrene is originally a liquid substance, which is mixed with a hardening agent that results in a solid substance (polystyrene). This change of properties indicates a chemical change. If we were able to observe this reaction we might be able to make note of other changes in properties, however this fits the basic definition that a chemical reaction is when two substances are mixed and their properties change. We also know that the deeper definition of a chemical reaction involves the rearranging of bonds between molecules, which is clearly shown by the before and after structural diagrams. It is obvious that the 3 styrene molecules are not the same structure as the new polystyrene, as there are no carbon double bonds, and the dimensionality of the structure changes as well.
   b. The source of the heat comes from the fact that the bonds being formed release more energy than the bonds being broken require to break. This change in energy indicates that this is an exothermic reaction. This can be illustrated more clearly with bond energies, which are the amounts of energy bonds require to be broken or release when they are formed. For a carbon-carbon single bond, this energy is 5.8x10^-19 Joules and a carbon=carbon double bond it is 10.2x10^-19 J. In the case of 3 styrene molecules forming the polystyrene molecule depicted, three of these double bonds are broken, and 6 carbon-carbon single bonds are formed (considering just one end of the chain as another carbon single bond, because the other end could be associated with another styrene added which would change the number of double bonds). This means that 30.6x10^-19 J of energy are required to break the bonds, and 34.86x10^-19 J of energy are released when the new bonds form. This gives us a net change in energy of 4.2x10^-19 J out. This proves that it is an exothermic reaction, since the net energy change results in energy out. This energy out would increase the temperature of the paste, which is why this is observed.

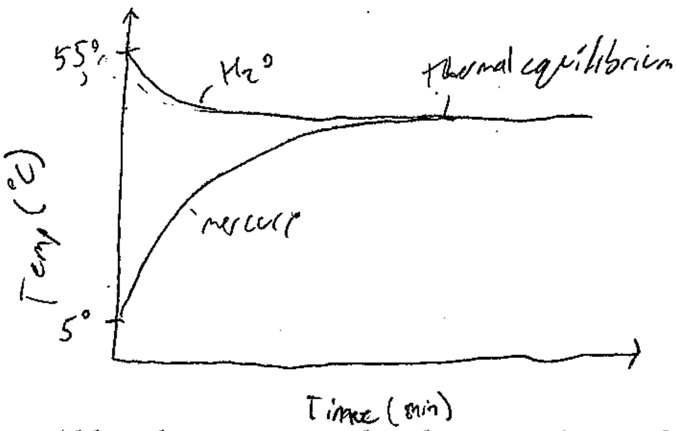
6. a. A radiator protects the engine from overheating because as the liquid flows to the engine, it absorbs some of the heat the engine produces. This warmer liquid continues to flow through this cooling system to the radiator. If the honeycomb structure has passageways for the liquid to flow, it will flow through this structure, and as air passes through this metal honeycomb, it takes away a lot of the heat. This is because the warm liquid transfers its heat to the metal of the radiator, which is a good conductor of heat (because it's metal). Once the metal heats up, it transfers its heat to the air that is

blowing through the radiator as the car moves. This air, through convection, takes away the heat from the radiator, essentially cooling down the liquid, which flows inside of it. This cooled down liquid flows back into the engine, where it heats up again and the process continues. If the liquid doesn't actually flow through the honeycomb, and just the tubes around it, it still works the same way, however the heat is only transferred from the liquid to the metal wherever it is in contact, and the more surface area, the more efficient this would be. This all goes back to the law of thermodynamics, which says things in contact with each other will reach a thermal equilibrium. Thermal equilibrium is not necessarily reached in this system because the water is flowing through the system meaning it's only in contact with the hot engine for a short period of time, so it only absorbs some of the heat as it passes through. Overall, conduction of heat from the engine to the liquid, then from the liquid to the metal in the radiator is what moves the heat away from the engine. Convection from the air flowing into the radiator is what takes the heat away from the system entirely, cooling off the engine.
b. One condition under which this system would fail to protect the engine would be if the liquid in the radiator did not have a high enough boiling point to remain in the liquid phase during this process. If the liquid boiled because of the heat of the engine, it would turn to gas and create too much pressure on the inside of that system, likely causing it to burst somewhere. I believe this is the reason why the steam comes from your hood when the engine overheats. That's why this coolant solution used must have a very high boiling point, but also a low freezing point so that it wouldn't freeze when the car is off and it's cold outside. Another scenario where this system would fail to protect the engine would be if not enough air is getting to the radiator. This could be because the honeycomb is clogged with dirt/mud, or because the car is not moving or in an environment without a lot of air. Any of these air flow obstructions would lead to the engine overheating because the air would not be able to come in contact with all the surface area of the radiator, and would not be able to take as much of the heat away. If the liquid going to the radiator is not cooled off by the air, then it would go back to the engine still very hot and would probably boil causing the same overheating problems previously mentioned. This would be a case of poor convection, and the liquid would likely boil and expand causing the gas to try to escape somewhere.

7. a. Just after pouring them into the two containers, I believe that they would both be at the same temperature (room temp roughly 23 degrees Celsius). This is because of the law of thermodynamics about thermal equilibrium. In this case the equilibrium would be between the air and other items in the room and the liquid. If the liquid was cold to start or warm to start, it would eventually reach the same temperature as the room, so pouring them into this container after they were left out in the room all day would likely yield a temperature of about 23 degrees Celsius. Depending on whether the liquid was colder or warmer than the room temperature to start, it would either gain heat or lose heat from/to

the air through convection. It would also reach a thermal equilibrium with whatever it is sitting on through convection. This is why I believe they would both be 23 degrees to start.

b. Graph:




c. Although mercury may be a better conductor of heat because it is a metal, I disagree with the statement. This is because the system has to reach a thermal equilibrium. When the student says the mercury will reach its final temperature more quickly than water, they are talking about a predetermined final temperature. However, if the mercury were to reach some temperature that the student presumed was its "final temperature" then it would be at a temperature different than that of the water. So, if these two liquids are at different temperatures, thermal equilibrium has yet to be reached, and this final temperature that the student is talking about doesn't really make sense, because it wasn't the final temperature after all. If the student was talking about the correct final temperature, then the water and the mercury would both take equal amounts of time to reach this temperature, because they were both in the container for the same amount of time, and the final temperature isn't reached until both substances are at the same temperature. This means they both took the same amount of time. The student might also mean to say that mercury might experience a greater change in temperature, but this doesn't mean it reaches the final temperature more quickly than water, because again it takes them both the same amount of time to reach that thermal equilibrium.

d. This result comes from the fact that water is a substance with a very high specific heat (4.186 J/g°C). Specific heat is the amount of heat required to raise 1 g by 1 degree Celsius. Mercury has a much lower specific heat (.140 J/g°C). This means that it requires much less energy to raise the temperature of mercury than water. This comes from the chemical properties of these substances. Specifically, water is a very polar molecule, which keeps its molecules very closely attracted to one another. This is because the oxygen molecule has a much higher affinity for electrons, creating a partial negative charge on the oxygen side and a partial positive on the hydrogen side. Increasing movement (therefore increasing kinetic energy therefore increasing temperature) is much more difficult in water than many other substances. So, if there is a certain quantity of heat in the system, which does not escape, the temperature of mercury will rise much faster than the temperature of water will sink. This would result in a thermal equilibrium much closer to water, so 40 degrees makes a lot of sense. One thing that helps us understand this property of water is the fact that the earth's oceans and bodies of water help to keep our temperature relatively stable.

8. Unheated waterbeds were likely uncomfortable for sleepers because they would draw a lot of the heat from person, making them feel cold. Humans have a body temperature of about 98.6 degrees Fahrenheit, whereas the room temperature may be around 70 degrees F. This means that as the waterbed sits during the day, it would reach a thermal equilibrium with the air in the room, so when you got in bed at night it would be about 70. As previously mentioned, water is a great absorber of heat, without having much change in temperature because of its specific heat. When you lay on the waterbed, through conduction, heat is transferred from your body to the waterbed in an effort to reach equilibrium. The body has a very slim range of temperatures where it likes to be at, so the body temperature dropping because of this heat loss to the waterbed would likely cause you to shiver. This shivering is a neural response that comes from thermoreceptors on the skin, which send signals to the brain that the skin is cold. The brain responds by sending a signal causing the muscles to rapidly contract and expand in an effort to generate more heat in the body to warm you back up. So, due to water's great ability to absorb heat, sleeping on a non-heated waterbed would probably result in a poor nights sleep. One solution to this problem as opposed to heating the water bed would be to put some sort of insulator between you and the bed, like a foam mattress pad with lots of air space in it. Air is a great insulator because it conducts heat very poorly. This would add a barrier, which would slow the heat loss through conduction.

April 22, 2015
CHEM 444A.H01

**Exam Two Take-Home**

1. **Explain where the heat and color progression of the glow come from.**

A conventional electric oven is powered by electricity. Inside the oven, there are two "heating elements," located at the top and bottom of the oven. These elements are composed of conductive material, which converts electrical energy to heat though resistive heating. In this process, the energy current encounters resistance and as a result, the heat produced radiates from the heat element to the food being cooked.

The heating elements are activated by the temperature control, which is set to a desired temperature by the chef. When either heating elements is activated, they appear unchanged initially, but the air temperature inside the oven in increasing. This is because electricity is beginning to enter into the element very quickly, causing the temperature of the element to rise, thus radiating heat to the air inside the oven. As more energy that passes through the heating element, the greater the temperature of the heating element. The heating element becomes much hotter than the cooking temperature, set by the cook, in order to bring the oven to the required temperature in a short period of time. In this heating up process, the extreme high temperature reached is capable of emitting visible light producing the color red. Once the oven's thermostat reaches the correct temperature, the heating element cools down to a lower temperature in order to maintain a consistent temperature. This cooler temperature emits visible light producing an orange or yellow shade instead of red.

2. **Compare and contrast baking and broiling in terms of how heat energy gets from the heating element to the material being cooked.**

Baking and broiling are two different cooking methods that can be performed by an oven, using the two heating elements. In order to bake a cake or a loaf of bread, the bottom heating element is used as the heat source. This process involves heat transfer through convection, the flow of heat via bulk movement of a fluid, either air or liquid. As energy is added to the system, the bottom heating element gains energy and transfers heat to the air. These heated air molecules, which are moving faster due to an increase in kinetic energy, then collide with slower moving molecules in the air and in the food being baked, resulting in the food heating up. In baking, foods are heated more evenly because the heat is coming from all sides, which is why the method is used for bread or cake.

Although broiling uses a heating element, as does baking, it uses the opposite element. The heat source involved in broiling is the one located at the top of the oven because the process is not intended to cook food all the way through. Instead, broiling is used to char foods, such as steak. In the process, the food is being heated by infrared radiation, the transfer of energy in the form of waves as light. The food being broiled is placed very close to the top heating element to allow for energy radiation to the food, thus heating it. Broiling is a popular method for cooking steaks because it cooks the outside more than the inside, allowing for consumption and the preservation of flavor.

3. **Explain why the difference in results when baking cookies on a simple metal tray, and one that has two layers of metal separated by a narrow air gap.**

The traditional, flat metal cookie sheet often results in burnt cookie bottoms because the heat source is located on the underside of the cookies in the baking process. The metal tray, a good conductor of heat, sits between the heat source and the cookies, and speeds up the baking process for the bottom of the cookies. The tray absorbs heat from convection, as do the tops and sides of the cookies; however, metal is a good conductor of heat, and the cookies are in direct contact with the metal, thus allowing a faster transfer of heat from the metal to the bottom of the cookie through conduction. The bottom of the cookies gain more heat while baking, resulting in burnt bottoms, while the top of the cookie slowly gains heat from the air through convection.

The use of a two layer metal cookie sheet, separated by a narrow air gap prevents the bottoms from burning because there is more space between the tray that the cookies are sitting on and the heat source, which decreases the temperature of the top tray holding the cookies. Since the top tray does not get as hot, less heat is transferred to the cookies by conduction. In addition, the pocket of air allows for air circulation underneath the top tray. This circulation method transfers heat to the top tray through convection, which is the same way that the top of the cookies are being heated. In turn, this equalizes the baking time necessary for the tops and the bottoms of the cookies. The air pocket acts as a buffer to heat, preventing the top tray from getting too hot, leading to evenly baked treats.

4. **Explain how water is heated to a boil in a tea kettle and in a microwave and why the microwave is faster.**

When boiling water in a tea kettle, more than one method of heat transfer is involved. Heat is transferred from the source, located beneath the kettle, to the pot through conduction because the heat source is in direct contact with the metal. The heated metal then transfers its heat to the water molecules situated at the bottom of kettle through conduction, due to their direct contact. As water molecules gain heat, their density decreases, causing them to rise, thus forming convection currents. The remaining water is heated slowly and consistently by convection; cooler water flows down to take the place of the rising warm water, allowing for the transfer of heat to bring the water to a boil.

Boiling water in a microwave only requires one method of heat transfer, electromagnetic radiation. The water is heated by waves of energy moving through space, which affects the molecules randomly, rather than systematically like in kettle boiling. The energy waves stem from various locations throughout the microwave, resulting in a non-uniform heating process. The lack of uniformity in heating causes hot and cold spots to develop within the water, while the water in the kettle is consistently heated.

Boiling water in a tea kettle requires heat to be transferred from the source, to the kettle, and then to all of the water molecules within the pot, while microwave boiling uses waves of energy to excite individual water molecules. These energy waves generate heat rapidly within each molecule that interacts with the energy wave. Heat is transferred directly in microwaves, while in the kettle, a longer transfer process must be undergone to excite the molecules enough to boil. This explains why boiling water in the microwave takes less time than boiling water in the tea kettle.

5. **a. Is there a chemical reaction going on here? Justify your answer.**

In the situation described, as the paste hardened, it was warmer to the touch than it had been at the start, which was confirmed by a thermometer. The change in temperature indicates that a chemical reaction occurred. A chemical reaction is a process that involves changes in the structure or properties of the two or more participating substances. In this example, the product was warmer than the original reactants involved, indicating that heat was released. The release of heat determines that an exothermic reaction took place because the only way for a temperature change to occur by the combining of two substances is if the properties of the hardening agent and the sticky liquid changed to form a new product.

**b. What is the source of the heat? A better answer will include a quantitative argument.**

In this exothermic reaction, the heat source is the breakage and creation of bonds. Exothermic reactions are characterized by the decrease in chemical energy, and an increase in heat energy, thus netting to no change in energy, which displays conservation of energy. In any chemical reaction, bonds in the reactants must be broken, which requires energy to be taken in. After the necessary bonds have been broken, new bonds between atoms in the products develop, resulting in the release of energy. If a reaction requires less energy to break the bonds than the amount of energy needed to create new bonds, energy is released, thus causing a temperature increase. If a reaction requires more energy to break the bonds than the amount of energy need create new bonds, energy is taken in, resulting in a temperature decrease. The paste material increased in temperature, displaying an exothermic reaction, which determines that the creation of new bonds required more energy than the breakage of previous bonds.

In quantitative terms, the energy required to break the three double bonds between the carbon molecules is $30.6(10^{-19})$ Joules. The energy required to create the six single bonds between the carbon molecules in the product is $34.8(10^{-19})$ Joules. These values prove that more energy was needed to create the bonds than to break the bonds, resulting in a release in energy, which can be felt by an increase in temperature.

6. **a. Explain how the radiator protects the engine from overheating.**

Radiators are heat exchangers responsible for moving heat from one medium to another to promote heating or cooling. These devices are crucial in vehicles, as they protect engines from overheating. The car engine is made up of various moving parts to burn fuel, which generates heat. The engine's temperature must be maintained in order for the vehicle to operate. The radiator's job is to reduce the temperature of the engine through the use of a coolant. The engine and the radiator are connected to one another with hoses, which allows the coolant to pass between the two devices. The liquid flows from the radiator into the engine, where it removes heat. The liquid gains heat because it is at a cooler temperature than the engine. The liquid flows back to the radiator, which is structured with small tubes, allowing the heated liquid to flow through the spaces. Upon doing so, the liquid loses heat to the surrounding air, resulting in the cooling of the liquid. The cool liquid flows back into the engine to remove heat in a cyclical patter, ensuring the continued operation of the engine by maintaining its temperature.

**b. Suggest two conditions under which this system might fail to protect the engine. Explain why those conditions would cause a problem.**

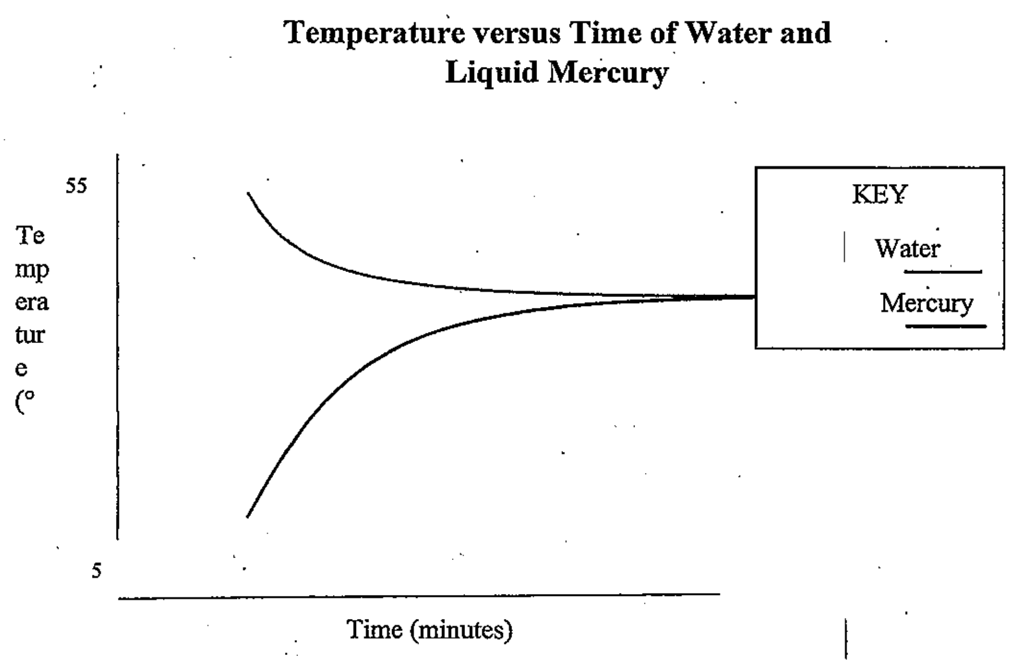
Although the availability and convenience of water entice some to consider the liquid as radiator fluid, the radiation system would fail to protect the engine if it was used. Water is not a good choice because it freezes at 0°C, and in cooler climates that commonly see temperatures below 0°C, the fluid will freeze, thus causing the engine to freeze. If the vehicle will not experience temperatures below freezing, water is still not a good choice because water's boiling point is 100°C. Even in normal use, engine temperatures can exceed 100°C, causing the water to vaporize; water in the gaseous state will not cool the engine, causing engine failure. Instead, an antifreeze coolant, or a water and coolant mixture, should be used because it has a lower freezing point and a higher boiling point than pure water. These properties establish antifreeze as the appropriate choice to be used in vehicle radiation because it can withstand more extreme temperatures, allowing it to absorb more heat in order to effectively cool the engine.

In addition to the use of inappropriate substances as radiator fluid, obstructions within the radiator structure can cause system failure. As time progresses, old radiator fluid can leave behind residue, or vehicle accidents can leave dents in the radiator's structure, which prevents smooth passage of heated liquid through the device. These obstructions reduce the direct contact between the heated liquid from the engine and the air, which prevents the liquid from releasing heat to the air. If the liquid is not able to cool down effectively by transferring its heat to the surrounding air, it will not be able to remove as much heat from the engine because the temperature difference will be less significant. The liquid that did not release as much heat, due to its reduced contact with air, will not take as much heat from the engine because less heat needs to be transferred from the engine to the coolant in order to reach equilibrium. If the coolant cannot remove enough heat, the engine will overheat, resulting in a failure in the radiation process.

7. **a. Describe what you expect the temperatures of the two liquids to be just after pouring them into the containers. Explain your expectations.**

Since both the water and the mercury have been sitting out on the lab bench since yesterday, I would expect their temperatures to be exactly the same after pouring them into the containers. The temperatures of the liquids would read the room temperature because they have been exposed to the same environment for a duration of time. The time that the materials sat out allowed for the liquids to reach thermal equilibrium with the room. When the materials were initially set out yesterday, they had their own temperature. If the liquids were at a higher temperature than the room, heat would transferred from the liquids to the room, causing the liquid temperature to decrease and the room temperature to increase. If the liquids were colder than the room, the heat from the external environment would have transferred from the room to the liquid, causing a rise in the liquid's temperature and a fall in the room temperature. The same basic process would occur if one liquid was warmer than the room and the other was cooler; whichever body was warmer would transfer heat to the cooler body, causing the warmer object to cool, and the cooler one to heat up. In any of the three cases, heat would be transferred until the liquid and the room reached thermal equilibrium with each other, which would occur while the liquids sat out for several hours.

**b. Sketch a graph showing both temperatures over time. Label appropriately, but only worry about qualitative accuracy not quantitative accuracy.**




**c. "I expect the mercury to reach its final temperature more quickly than the water will because mercury as a metal is a better heat conductor." Do you agree or not with this statement? Explain.**

I do not agree with this statement because although liquid mercury is a better heat conductor of heat, as it is a metal, thermal equilibrium is the condition in which two substances in contact with one another no longer transfer heat between them. Heat energy is transferred from the warmer temperature object to the colder temperature object until they reach the same temperature, known as thermal equilibrium. The water is transferring its heat to the liquid mercury because it is at a higher temperature. The transfer will continue to occur until a common temperature is reached; as the water's temperature decreases, the liquid mercury's temperature will increase until there is no longer a heat transfer between the two, and they reach the same temperature. The increased conductivity of the mercury will help the two substances reach equilibrium faster than a less conductive substance because heat can transfer quickly between liquid mercury molecules, thus heating the whole metal faster. Thermal equilibrium, however, is the point where the two liquids equalize in temperature; therefore, it is not possible for one substance to reach the final temperature, equilibrium, before the other.

**d. The number of molecules or atoms per unit volume is slightly larger for mercury vs. water. Nevertheless, the final temperature will be about 40°C, closer to the initial temperature of water. Explain how that could result.**

Earlier in the semester, we did a series of experiments involving mixtures of different volumes of water at different temperatures. When volume was held constant, and temperature was the variable, the final equilibrium temperature of the mixture fell exactly in between the two initial temperatures. If there was a greater volume of warm water than cold water, the equilibrium temperature of the water was closer to the initial temperature of the warm water, relative to the volume quantities. The same trend was true when there was a greater volume of cold water; the final temperature was closer to the initial cold temperature, relative to volume.

Since there are more mercury molecules per unit, I would expect the temperature at equilibrium to be closer to the mercury's initial temperature, if the volume of water and mercury were the same. I would expect this because the water's heat would need to be dispersed among more molecules, causing the heat to thin out over all the molecules. This would result in an equilibrium temperature closer to the initial cold substances temperature. Because the final temperature of 40°C is significantly closer to the water's initial temperature, I believe that there must have been a greater volume of water than mercury.

**8. Explain why unheated beds were uncomfortable for sleepers, using fundamental principles.**

Sleeping on an unheated waterbed provides a very unpleasant experience for those seeking a good night's sleep. Without a heating source, the bed of water is at a lower temperature than the sleeper's body temperature. Whenever two bodies come in contact with one another, heat is transferred. Heat is always transferred from the warmer body to the cooler body until the two objects reach equilibrium. This is the case when the sleeper lays himself on the bed. Since the human body is warmer than the unheated waterbed, the bed will absorb heat from the sleeper, resulting in a decreased body temperature of the human. As the bed absorbs heat energy, its temperature will rise. This heat transfer process will continue to occur until the human body and the water reach the same temperature, thermal equilibrium. The sleeper will experience an extreme loss of heat, causing him to feel very cold and making for an unpleasant night of sleep.

N16

4/24/2015
Fire and Ice

CHEM 444A Exam 2

1 – 4 → Cooking Problems

1.) As shown in the diagram of the conventional electric oven, the two "elements" are mounted to both the top and bottom of the oven. When they get hot, they turn red, and then eventually orange and yellow. This is due to electromagnetic radiation. When the heat is applied to these two heating elements, the atoms in the elements begin to rapidly vibrate, which emits electromagnetic radiation, which creates visible electromagnetic waves. Depending on what temperature the heating elements are at, the atoms will be moving at a different speed, which effects the color that we can see. There is a color progression as the atoms emit greater electromagnetic radiation, which goes in this order: red, orange, yellow, green, blue, purple, and when all colors are seen at once, we see white.

2.) Baking and broiling differ in terms of how heat energy gets from the heating element to the material being cooked. When baking bread, the bottom heat element, or bake element, is turned on, bakes the bread *mainly* through the processes of convection and conduction. When the bake element is turned on, heat energy is brought upwards by way of convection, which brings heat up through air flow (hot air rises). When the heat energy surrounds the bread, it enters the bread by way of conduction, which allows heat energy to pass through the metal. Metal is good conductor of heat energy due to it delocalized electrons, which allow energy to readily pass through it. On the other hand, the broiler gets to the steak *mainly* by radiative heat. The broiler heats up to an extremely high temperature and emits infrared radiant waves downward, directly down to the steak being cooked.

3.) When baking cookies on a standard, single-layer tray, the bottoms of the cookies are often burnt before the tops are fully cooked. This is because metal is a good conductor and the single layer permits heat energy to readily pass through the pan and enter the bottom of the cookies at a fast rate. Once the heat energy enters the bottom of the cookie, it takes longer for the energy to conduct through the middle of the cookie to reach the top, so the bottom often gets burnt. However, a better cookie tray has two layers of metal separated by a narrow air gap. In this case, energy passes through the first (bottom) layer of the pan, and enters the air gap that stands between the next layer of metal. The energy has to rely on convection to reach the surface of the next layer. This air pocket slows down the speed at which energy reaches can pass through the next layer into the cookie, preventing the burning of the bottoms of the cookies.

4.) On a traditional, circular heating element on top of an oven, a tea kettle reaches boiling point by means of conduction and convection. When the circular stove top, which is in direct contact with the tea kettle, is turned on, heat transfers through the kettle by way of conduction. Conduction is the transmitting of heat through the collisions between neighboring molecules. Once among the water, the thermal energy travels throughout the system by means of convection. On the other hand, a microwave oven will boil water at a much faster rate, due to the radiation. Microwave ovens send microwaves directly into the water being heated up, and the water absorbs the microwaves. When these waves are absorbed, they excite the water molecules throughout the whole system, which causes the water to heat up. This is much quicker because it effects the water all at once and can be absorbed by the water all at once.

5 – 6 → Automobiles

5.) A.) Yes, a chemical reaction is occurring here. When the liquid styrene is combined with the hardening agent, a new material is formed, call polystyrene, which is a solid. This fulfills the definition of a reaction: two or more materials combine to form a material(s) with different properties than before.

B.) Since the paste was warmer to the touch, and measured to be hotter with a thermometer, it can be concluded that this was an exothermic reaction. In an exothermic reaction, the reaction released heat to the environment, which is why the material is hot to the touch. Since bonds are forming during the Bondo hardening process, energy is being released from the reaction. Overall, the amount of energy gained from the breaking of bonds during the reaction was less than the amount released from the reaction. If this was an endothermic reaction, we would expect to feel a colder temperature, because temperature would be absorbed from the environment, but that is the not the case here.

6.) A.) The radiator protects the engine from overheating. Water is pumped is a cycle; from the radiator, through metal pipes that attach to the engine, through the engine, and then back to the radiator. As water enters the engine, heat enters the water by conduction from the hotel metal that surrounds it, and the hot water returns to the radiator. Once at the radiator, the honeycomb allows for evaporative cooling; the heat energy can leave the water through the evaporation, which can pass through the honeycomb out into the air. The resulting water inside the radiator is then cool again, to repeat the cycle.

B.) Two conditions under which this system might fail to protect the engine:

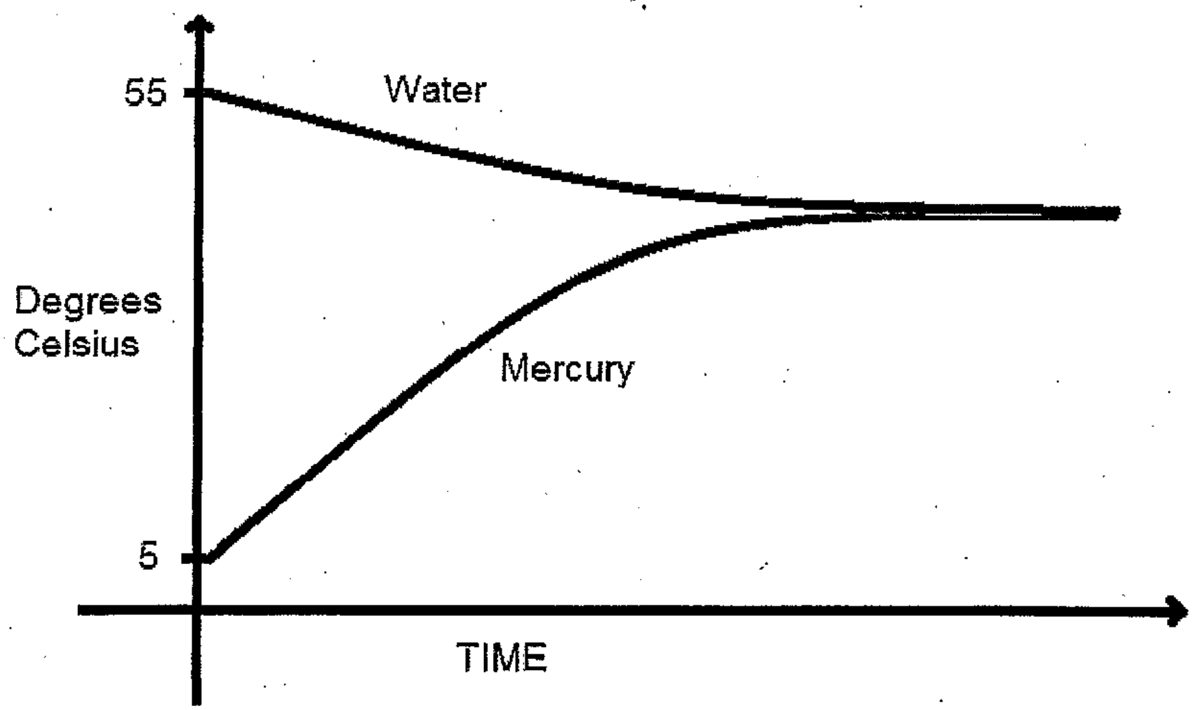
1.) Clogged/broken metal pipes that run through the radiator-engine cycle. This would cause a problem because water could not reach the heat from the engine and/or return back to the radiator to undergo evaporative cooling. This would prevent heat from being able to exit the engine, which would cause the engine to overheat.

2.) No more water/coolant in radiator. The water/coolant is the only way for heat to exit the engine. If there was none of it, nothing would pass through the engine to acquire the heat and evaporate through the honeycomb. This would cause overheating.

7 → Mercury and Water Containers

7.) A.) I would expect both substances to be close to room temperature. With the air surrounding the substances, conduction will occur from the air into the substances. Since this process is occurring over a whole day's time, both substances would reach room temperature. Due to the zeroth law of thermodynamics, two objects come to intermediate temperature when they come in contact, so the mercury and water would raise to air temperature. (Due to the volume of air, air temperature change is negligible.)

B.) As shown in the figure below, the mercury and water come to an intermediate temperature. This is due to the zero-th law of thermodynamics, which states that two objects come to an intermediate temperature when combined. (see next page)




C.) Another student says, "I expect the mercury to reach its final temperature more quickly than the water because mercury, as a metal, is a better heat conductor." I agree with this statement. Conductivity is the process by which heat energy is transmitted through collisions of neighboring molecules. Although the rate at which energy transmits through the walls between the water and mercury will be the same, mercury is a better conductor than water so energy will be able to travel through mercury at a faster rate, raising the heat at a faster rate.

D.) The number of molecules or atoms per unit volume is slightly larger for mercury vs. water. Nevertheless, the final temperature will be about 40 degrees Celsius, which is closer to the initial temperature of water. This is due to the high conductivity of mercury compared to water, and the number of molecules per unit. Since the mercury is very cold, when coming to an intermediate temperature with the water, it heats up from energy transferred from the water. Since mercury is very conductive and there are more molecules per unit volume, the collisions that allow energy transfer from molecule to molecule during the conduction process occur at a faster rate, and they do it more quickly in general because mercury is very conductive. In summary, the mercury is heating up at a faster rate than the water is cooling down, which brings us to an intermediate temperature of 40 degrees Celsius, which is much closer to water's initial temperature than mercury's.

8 → Water Beds

8.) Unheated water beds would be very uncomfortable for sleepers. The reason behind this stems from the zero-th law of thermodynamics. When two objects come in contact (In this case, the water bed and the human body), these two objects come to an intermediate temperature. When the water in the water bed is colder, heat energy from the body will enter the water through conduction. The thermal energy from the human body would transmit through the water bed container by conduction. The result is the sleeper feeling much more cold, which would end up in a very uncomfortable night sleep.

P14

CHEM 444AH April 23, 2015

Exam 2

1. When an electric oven is "turned on", electricity is used to heat up the heating elements on both the top and bottom of the oven. These heating elements consist of wires surrounded by a metal sheath. As these elements are excited by electrical current, they give off radiation, heating the oven. If these elements get hot enough, they will give of radiation equal in energy to that of the visible electromagnetic spectrum and begin to glow. This glow starts as red, as that is the end of the spectrum carrying the least energy. As it gets hotter, more energy is given off and the photons released become orange and then yellow. This color difference is similar to that of stars of different temperatures.

2. When baking bread, conduction is the main source of energy transfer. As the bottom heating element gets hotter, direct contact with the pan the bread is in allows heated/excited metal molecules of the heating element to collide with and transfer energy to the molecules of the pan. These molecules, also through convection, heat the bread. When cooking a steak, radiation is the main source of energy transfer. The steak broils in the radiation emitted by the heating element at the top of the oven. As the metal sheet gets heated by radiation, some conduction occurs between the sheet and steak as well.

3. If the flat metal tray is a good conducter of heat, then by convection energy will quickly travel from the heating element to the bottom of the cookies, burning them. Adding this layer of air and extra metal layer slows the rate at which energy is conducted to the bottom of the cookie, giving the heated air in the oven to bake the top of the cookies as well. The extra air and metal gives the bottom slightly more insulation.

P14

4. Boiling water in a tea kettle uses conduction of heat from the stovetop to the metal bottom of the ketal to the water inside. Energy needs to travel through the metal and the water is slightly exposed to outside air via the spout, making this a slightly slower method of heating. In the microwave, radiation is used to directly heat the water quickly and though the water is being exposed to air, that air is being heated as well. On top of that, the mug it is being heated in transfers energy to it using convection. This combination of conduction and radiation makes the microwave much faster.

5. a. Yes there is a chemical reaction going on. Upon being mixed with the "hardening agent" styrene is converted to polystyrene, a molecule with chemical and physical properties different than that of the reactents. This is evident by the structure of the molecule. Evidence of an exothermic chemical reaction is found in the release of heat with the mixing of styrene and the "hardening agent".
b. The source of heat is found in the building of new C-C bonds between styrene monomers. While it takes energy input to break bonds, energy is released when new bonds are built. So as each styrene monomer is added on to the polystyrene chain, a C-C bond is formed and $5.8 \times 10^{-19}$ Joules of energy is released. This release of energy makes the paste feel warm.

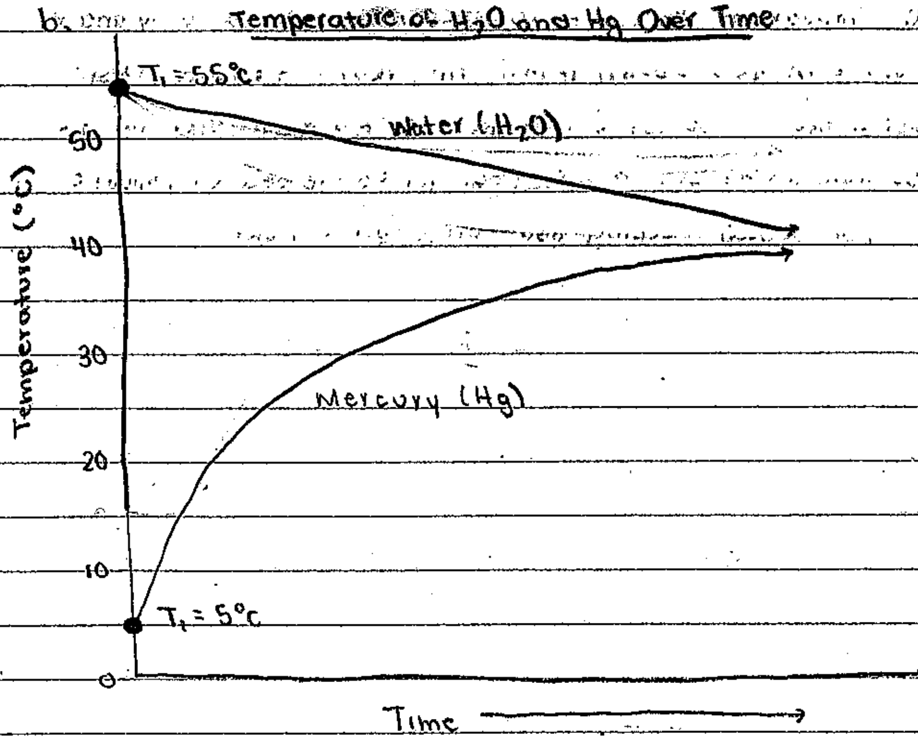
6. a. As the coolant flows through pipes in the engine it becomes heated up by contact with the heat being produced. Through convection and the flow of water, this heat is carried to the radiator. The honeycomb structure on the frontside of the radiator allows air to flow through the front grill of the car and through the radiator. By convection, this flow of cool air cools the heated water flowing through the radiator. The now-cooled water returns to flow through the engine and pick up more heat, preventing the engine from overheating.
b. One condition in the radiator might fail to protect the engine is

P14

if temperatures are frigid. If the coolent solution freezes while travelling through the pipes of the engine and radiator, you run the risk of pipes bursting, as coolent is part water, which expands when it freezes. Another situation in which the system would fail is if the radiator becomes damaged, impeding either the ability of the coolant to flow through the system or the ability of air to flow through the radiator and cool the system. Both these damage issues would prevent the ability of coolant ~~to cool~~ the engine and you run the risk of overheating.

7. a. You would expect the temperatures of both to be equal at around 23°c (room temperature) when poured into the container as they have been sitting on the lab bench for an extended time.

b. Temperature of $H_2O$ and Hg Over Time




c. Yes. A higher thermal conductivity will allow heat transferred to the mercury via conduction to travel more quickly to the rest of the mercury molecules. Because water is less efficient of a conductor, heat will take longer to travel through it, keeping it hotter for longer. This will cause the final temperature of the two to be closer to the initial temp of the water.

P14

d. The final thermal equilibrium temperature of two substances that come in contact with one another involves three variables: the initial temperatures, masses, and specific heats of the substances. Despite the mercury being denser, the final temperature of the system will be much closer to the initial temp of water because water has a much higher specific heat (4.184 J/g°c at 25°c) than mercury (0.14 J/g°c at 25°c). This means it takes much more energy to change the temp of water by 1°c than it does mercury.

8. The problem with an unheated water bed is that it would be uncomfortably cold to sleep on. Body temperature is around 37°c where as the room temperature water in the bed is about 23°c. Throughout the night, conduction between your body and the bed will cool you down, transferring heat to the water. Despite this, the bed is too large and there is too much water for the temperature of the bed to ever heat up, so the bed will remain colder than your body, keeping you feeling cold all night.

Q25

CHEM 444AH

Professor Bauer

Due: April 24, 2015

Take-Home Exam

1. The heat used in an electric oven comes from the building's electricity. Electric ovens are usually connected to the electricity by plugging it into an electrical outlet. The heat energy of the electricity transfers from the power source to the oven when the oven is in use.

Light photons of different colors radiate different levels of heat energy. Light photons that radiate more heat energy are brighter in color, such as white and yellow. Darker colored lights radiate less heat energy. As the temperature inside the oven increases (or the amount of heat energy increases), the light we see changes to brighter colors. First it is red, then it becomes hotter and turns to orange, and finally it becomes even hotter and turns to yellow. Yellow light radiates a lot of heat energy.

2. The baking setting in the lower element of the oven gradually increases the temperature of the oven. The baking setting also allows the cook to set the oven to a specific temperature. When the oven gets enough heat energy, the thermostat will shut off the bottom element. When the thermostat reads a temperature that is too cool, the bottom element will turn back on. This regulates the oven to the desired temperature. The pan used to make bread is useful when using the baking setting because it will absorb the heat energy that is radiating from the bottom of the oven. The light radiates heat energy to the molecules of the pan. The pan then transfers the heat energy to the dough through conduction. This is a 'gentler' way to cook than broiling because it avoids burning the dough.

The broiling setting in the upper element of the oven increases the temperature of the oven as quickly as possible. Unlike the baking setting, the cook cannot control the final temperature of the oven. The upper element will radiate as much heat energy as it can. The light radiates a lot of heat energy at once to the pan, but also to the steak itself. The heat energy in the pan is then transferred to the steak by conduction. The steak is receiving a lot more heat energy at a faster rate, which makes this method good for blackening foods.

3. The baking setting in the electric oven radiates heat from the bottom element to the tray on the baking rack. With a simple metal tray, the heat energy is transferred from the bottom of the tray to the cookies by conduction. The heat is then transferred molecule to molecule throughout the cookie. However, the bottom of the cookies are almost always receiving the heat energy from the pan first, which leads to burning. The tray with the narrow air gap provides air circulation. The pan is still receiving heat energy through radiation from the bottom element, but less of that heat energy in transferred directly to the bottom of the cookies. Some of the heat energy with transfer to the air in between the two metal layers. This air will become less dense because the molecules are moving faster and the hot air rises. This hot air will transfer its heat energy to the top of the cookies while the bottom of the cookies still receive heat directly from the tray. Once the hot air loses heat energy and cools, it becomes denser and falls to repeat the process. Thus, the combination of radiation, conduction, *and* convection allows for evenly baked cookies rather than just radiation and conduction.

4. The traditional tea kettle on a stove top boils water primarily by convection. The heating element on the stove top transfers heat to the bottom of the kettle through conduction. The water at the bottom of the kettle receives this heat energy and its kinetic energy increases, causing it to move faster. This hot water is less dense and rises to the top of the kettle. Cool water replaces it on the bottom. After all the water is circulated and heated up, the water as a whole can begin to use the heat energy to boil and change phases.

In a microwave oven, heat is applied by radiation. Light waves carry lots of heat energy and transfer it to the object in the microwave. When you put water in a container in the microwave, the water is receiving heat energy from all angles. Heat energy is transferred from the light directly to the water and to the container by radiation. Then heat energy is transferred from the container to the water by conduction. Quickly, the water will have enough heat energy to boil. The water does not need to circulate in order to boil and it is receiving heat from the bottom, top, and sides, which is why it takes a lot less time.

5. a) Yes, I believe there is a chemical reaction here. A chemical reaction occurs when two or more substances are combined to create a new substance. In other words, two or more reactants interact with each other in a way that creates a new product(s). This process can be seen by a change in properties, such as color, texture, or volume. This process can involve break and

forming bonds. In this case, styrene molecules are mixed with the hardening agent to create polystyrene.

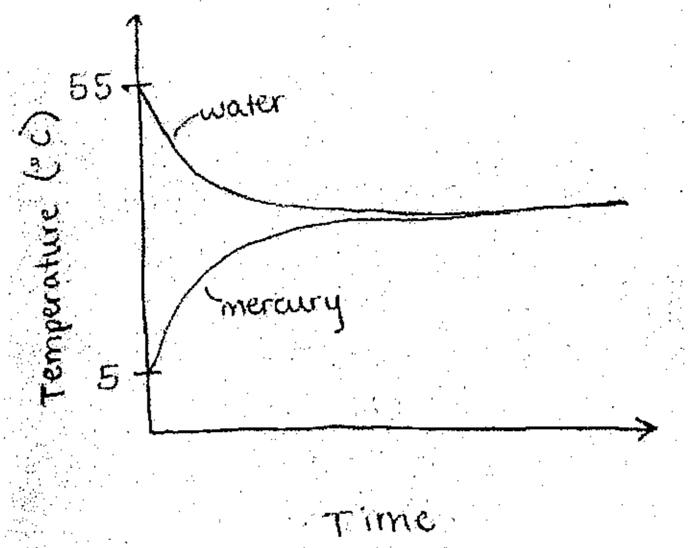
b) The reactants in this reaction are styrene and the hardening agent. When bonds are broken, energy is absorbed by the molecules. When bonds are formed, energy is released. Since you felt heat during the reaction, we can assess that this is an exothermic reaction. An exothermic reaction is when the formation of bonds release more heat than the breaking of bonds absorb. The source of heat in this reaction is from the formation of bonds.

6. a) The water or coolant solution that is pumped to and from the engine has to be a relatively good conductor of heat energy in order to successfully cool down the engine. When the water first flows to the engine, it is cool and does not have much heat energy. When it gets to the engine, the heat energy from the engine transfers to the water through conduction. This heats up the water, but also cools down the engine. The hot water then flows back to the radiator to cool down. This process essentially 'pulls' the heat away from the engine. The hot water that returns to the radiator will transfer its heat energy to the radiator. This allows the water to be cool once again and repeat the process. The radiator does not overheat from the hot water because air is circulating through the honeycomb structure in convection currents. Cool air molecules that are circulating through the honeycomb will absorb the heat energy from the radiator molecules. When the air molecules become hot, they are less dense and rise away from the radiator and out of the vehicle.

b) If there was nowhere for the hot air to escape the vehicle, then the vehicle could overheat very quickly. All the heat energy from the engine would not be released from the car. I'm by no means a car expert, but overheating in a car could probably cause a fire, explosion, or just a general shutdown of the car. Another problem would be if the honeycomb structure was clogged enough to prevent any air circulation. If the air cannot circulate and cool down the radiator, then the water would travel back to the engine with a lot of heat energy. The molecules of the water and the engine would increase in speed, possibly enough for the water to boil. The engine, radiator, and water would only increase in temperature and you may see steam (water vapor) coming out of the hood of the car.

7. a) I would expect the thermometers in both the water and the mercury to read at about the temperature of the room after just being poured into the container. While water and mercury

were sitting out on the lab bench, the molecules interacted with the air molecules. If the liquid molecules were cooler than the surrounding air, then the air molecules would have transferred heat energy to the liquid molecules until both the liquid and air were at equal temperatures (thermal equilibrium). If the liquids were warmer than the air molecules, then the air molecules would have absorbed heat energy from the liquids until the liquids cooled to thermal equilibrium.




b)

c) I agree that liquid mercury is a better heat conductor than water, because it is a metal and metals have 'free' electrons with a small mass. These electrons can move quickly and therefore transfer more energy at faster rate than water. However, I disagree that it will get to the thermal equilibrium temperature faster than water for this reason. Metals are good conductors, meaning they can transfer energy from one substance to another efficiently. This does not necessarily mean that the metal itself will increase in temperature because of this conductivity. As in the case with the Miracle Thaw, the metal could conduct heat from the table to the ice cube very well, but the Miracle Thaw itself was still very cool. Therefore, I believe the water and mercury will achieve thermal equilibrium at about the same rate.

d) The starting volumes of both liquids were never stated, so if they are unequal, then the thermal equilibrium will not occur at the exact midpoint of the two starting temperatures. If there is more water than mercury, then the ending temperature will be closer to 55°C than 5°C. This is because there will be much more heat energy overall in the water than the mercury. Since there is more total heat energy in the system, the equilibrium temperature must be higher. The energy is transferred from the water molecules through the molecules of the conductive panel to the mercury molecules. (This is called conduction because molecules are transferring energy by direct contact.) Because mercury has more molecules per unit of volume than water, there would need to be quite a bit more water than mercury in order for the thermal equilibrium temperature to reach 40°C.

8. Water beds without a heater can be described as a heat sink. When a warm person lays on the bed, the heat from their body is transferred through the mattress to the cool water molecules. Since there are much more cold water molecules underneath the sleeper than warm molecules in the sleeper, the thermal equilibrium temperature will end up being very cold. The sleeper will lose too much heat energy to be comfortable and relaxed. A heater will make the sleeper feel warm by raising the thermal equilibrium temperature. Another alternative is to put some sort of thermal, non-conductive material between the sleeper and the bed to keep the heat energy from transferring out of the sleeper and into the water.

R23

1/24/15

Spring Exam 2

1. In a conventional electric oven there is a copper wire that runs on the inside of the metal "heating element". Electricity is run through the copper in which the electric energy changes to heat. The copper heats the metal and the metal heats the rest of the oven by radiation. The reason the color changes is because of thermochromic properities. This means that the material will temporarily change color when it is exposed to heat. The warmer the metal the brighter it will become so the metal will start red and then as it heats up more and more it will get closer and closer to yellow/white. It works similarly to the thermochromic paper we use in class.

2. When you bake bread you are heating it by surrounding the food with hot air. In other words the oven is using convection to cook the bread. Heat is being released at the bottom and then it rises and helps heat the rest of the air which then heats the food. This can usually be done at a lower temperature but it requires more time to cook food. When you broil food you are heating the food by infrared radiation. The heat is radiated from the top of the oven unlike when you bake. This must be done at higher temperatures but it takes much less time to cook because radiation doesn't have to go through another medium like convection does.

3. When cookies are baked on a regular pan the warm air is cooking the whole thing but the bottom is being heated by conduction. Conduction transfers heat very effiecently and much faster than convection. When the pan has two layers the air gap allows the bottom of the cookie to also be cooked by convection. Therefore the whole process is cooked the same and the bottom won't be done

so much faster.

4. In the kettle the metal is being heated by the flame and then it is heating the water by conduction. The the water inside the kettle is being heated by convection as the heat is being transfered by mass motion of fluid. In the microwave the water is being heated by electromagnetic radiation. This way all the water is being heated up at once. That's why the microwave is so much faster because it can heat "all" the water while the kettle is only heating the bottom and requiring convection to transfer the heat throughout.

5. a There is definitely a chemical reaction going on here because bonds are being broken and need ones are being formed. Put simply, there is a change in the properties of the reactants to the product. It is seen here as the paste turns solid.

b. The source of heat is from the combination of the bonds breaking and reforming. In this case it is an exothermic reaction. You know this because heat is being released from the product. In other words the products release more energy than the reactants absorbed.
In this specific reaction 3 double C to C bonds were broken and 5 single C to C bonds were made (however the end Cs have to bond w/ something so I included them in the bond energies)

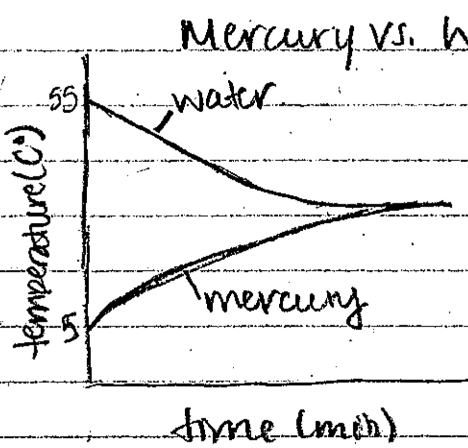
$9(6.9) + 3(10.2) = 92.7 \times 10^{-19}$ J (reactants) $\longrightarrow$ exothermic
$9(6.9) + 7(5.8) = 102.7 \times 10^{-19}$ J (products)

6a. In the radiator the coolant is pumped to the engine. There the engine is warmer than the coolant so the coolant absorbs some of its heat. The now warm coolant travels back to the radiator where air is flowing by the pipes. The air cools the metal and also the ~~[illegible]~~ coolant down. This way the engine is releasing heat and the coolant goes back to the engine "cold" again.

b. One condition where this system might fail to protect the engine would be if it's really hot outside. If the air isn't cold enough to cool the coolant back down then the engine ~~[illegible]~~ won't be able to release heat and it will over heat. Another condition would be if any of the pipes have a leak. This would eventually cause there not to be sufficient enough coolant to keep the cooling ~~cycle~~ going and again the engine would over heat.

7.a. If both the water and mercury had been sitting out over night I would expect them both to be room temperature because the differences in room temperature and water temperature would even out. Liquid all likes to be the same temperature so the heat would be released or absorbed until all the water and ~~a~~ the room temperature are the same.

b.



c. I believe that if the mercury and the water were completely seperate then this statment would be correct. I think since mercury is such a good conductor and the more e packed tightly together molecules of it could be moving at the same speed as room temperature faster than in the water. However if this is referring to the situation above I don't think that mercury would get there faster because now it is in contact with the air and water. The mercury on reaches its final temperature once it can absorb or release ~~hot~~ heat to both the air and the water.

d. This result could happen because of the amount of tightly packed molecules in mercury. Mercury has a higher density than water so when the molecules gain energy the move but they stay closer together. That way it can hold heat and doesn't need to absorb as much heat so the overall temperature is closer to the waters temperature.

(honestly not sure how this works, ~~but~~ would love to know)

8. Unheated water beds are uncomfortable to sleep on because you feel cold. Your body on a normal bed loses some heat to the bed but it is a solid so it can't move. By this I mean you only have to heat the part of the bed you are laying on. However for a water bed the water is constantly moving. Therefore you heat the water underneath you (conduction) but then it moves and tries to "spread" the heat through convection. With "new" water to "heat up" all the time you will constantly feel cold.

Take Home Test Page 1

① Electricity is conducted through the element, which causes heat to be radiated out away from the metal. The air will get hotter right away because of the radiating heat. However, the longer the elements are heated, the hotter they become until they have enough energy to also radiate visible light, which causes them to turn red or orange. Before this, the light being emitted was not in the visible spectrum because the wavelengths were too slow.

② When you bake bread, the heat radiates from the lower element to the bottom of the pan. Then, it is conducted through the pan into the dough. As the dough rises, it is also taking in heat from the sides of the pan by conduction.

When you broil steak, heat from the top element radiates down towards the steak. Since there is no metal surrounding the steak, conduction does not play as big of a role as with baking. However, the heat will also radiate to the sheet, which will conduct heat into the bottom of the steak.

③ The bottom of the cookies are being heated by conduction from the hot pan, while the tops of the cookies rely on heat from the hot air in the stove or heat that is conducted up through the rest of the cookie. Since air transfers heat more slowly than metal, it can act as an insulator between the metal sheets, thus slowing the cooking time of the bottom of the cookie to be more similar to that of the top. This is similar to how we used air trapped in Styro-foam cups to insulate hot water from cold water and slow the rate of temperature change.

(4) When heating water in a kettle, the heat must be conducted from the hot heating element to the bottom of the kettle, then through the kettle to the water. The heat source is only on the bottom of the kettle, so the sides of the kettle only heat the water as heat is conducted up the kettle and then into the water.

When water is heated in the microwave, heat is transferred through radiation. The microwaves, which transfer energy and heat to the water, contact the water from all different directions. This heats the water more efficiently than when conduction is used on the stove top.

Take Home Test pg 2

(5)

A) Yes, there is a chemical reaction occuring. This is because two liquid substances (the styrene and the "hardening agent") are interacting, which causes a change in characteristics of the substances. It is now polystyrene which is a solid substance. Further evidence of the chemical reaction is the increase in temperature of the material as it hardens. This indicates energy is being released due to the formation of new bonds.

B) The heat is being released when bonds are formed. This is because when bonds form, atoms must lose energy in order to come together. This energy is released into the surrandings as heat. While bonds are also breaking in this reaction, which requires energy input from the surrandings, more energy is being released from bond formation than is being absorbed. This can be proved by calculating the energy input to break bonds, $30.6 \times 10^{-19}$ Joules, and the energy released by forming new bonds, which is $40.6 \times 10^{-19}$ Joules. More is released than absorbed.

(6)

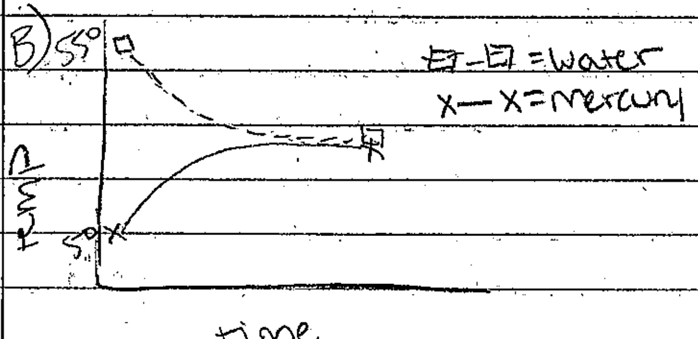
A) When the cool liquid from the radiator flows through the engine, it gains heat because heat goes from molecules with more heat to molecules with less heat. This occurs by conduction because the liquid is in direct contact with the engine. The hot coolant than flows back into the radiator. As it is pumped through the radiator, the heat it carried away from the engine is released to the surranding air, which is possible because of the honey comb structure and large surface area. This heat is transferred by radiation. The warmed air flows away and is replaced by cooler air, allowing the process to continue. When the coolant has traveled through the entire radiator, it has lost the heat it gained in the engine and is ready to be warmed again.

B) One potential problem with this system would be leak. If the liquid coolant leaks out, there will not be enough fluid to circulate through the system and absorb heat from the engine, so the engine will get too hot.

Another possible malfunction would be if the pump stopped working. The coolant would be in the system, but unable to circulate. Heat would not be carried away from the engine because the water would just get hot and stay there. Cold water would also be unable to flow into the engine. The movement of water is what enables heat to be transferred throughout this system, so both a leak and a failed pump, which result in lack of flow, would interfere with this process and cause heat to build up within the engine.

9

A) If both liquids had been sitting out at room temperature, I would expect both of them to be room temperature when poured into the chambers. This is because the liquids would have given off or absorbed heat to or from the surroundings (depending on whether they were hot or cold to begin with) until they became the same temperature as the air in the room. This occurs by conduction between the liquid, its container, and the air.

B)


Take Home Test pg 3

7 cont.

C) I do not agree with this statement. The end temperature for both water and mercury will be the same, and it will occur at the same time for both (when they reach thermal equillibrium). Mercury may be better at conducting than other liquids, but this means both substance will reach thermal equilibrium more quickly than if the mercury were replaced with a less conductive liquid.

D) Water has a higher specific heat capacity than mercury, which means it takes a greater change in energy to cause a change in temperature. While the heat lost from the water is not enough to change it's temperature greatly, it is enough to change the mercury's because it can hold less heat before changing temperature. One reason for this is mercury atoms are smaller than water molecules (which we know because there are fewer of them in the same volume), so it will take less energy to make mercury atoms speed up and increase in temperature. Since the mercury is changing temperature more rapidly than the water, the thermal equilibrium will be closer to water's original temperature.

8 The water in the bed will start at room temperature, which is much colder than the human body. When the person lies on the bed, the heat from his or her body will be transferred to the water in the bed. However, because water can hold a lot of heat before changing temperature, and because there is so much water in the bed, the bed will not heat up to reach thermal equilibrium

with the person's body for a long time. This means the person will feel cold for much longer than in a norma bed because the body's heat will be continuously lost to the water in the bed.

T19

CHEM 444A

April 21, 2015

Exam Two

1.) The heat generated by these elements is the result of radiation. An electric current travels through the element and is the source of the heat. When the element is first turned on there is no electricity traveling through it. As the amount of electricity cycling through increases, more energy is present and the coil becomes hot. The coil then gives off heat through radiation. This is the theory behind the change in color. When there is less energy present, the radiation being given off by the element has a longer wavelength. This radiation is not visible to the human eye and results in a lower temperature. As more and more energy is present and subsequently given off, the wavelength decreases. Red is the first color change seen because on the spectrum of visible light it has the longest wavelength. It is then followed by orange and yellow light.

2.) When baking bread, the goal is to cook the bread completely without burning it. This is accomplished by essentially surrounding the pan with hot air. The bottom element is turned on and the oven is given time to "pre-heat". The oven first begins to heat as a result of radiation. As the air becomes warm there is a movement of heat through convection currents. Hot air rises to the top of the oven and cooler air falls to the bottom. The cooler air is heated and the cyclical process continues. This allows for air throughout the oven to reach a common temperature. The pan protects the bottom of the bread from infrared radiation from the bottom burner (protects against burning). The top of the bread is simply cooked by hot air. When broiling, the goal is to cook meats similarly to how they are cooked on an outdoor grill. The top element is turned on to allow infrared radiation to cook the meat. Essentially, electromagnetic waves of energy are responsible for the transfer of heat. The pan is open on top, allowing these waves of energy to readily reach the meat.

3.) A traditional metal tray used to bake cookies conducts heat directly to the bottom surface of the cookie. The more sophisticated tray with an air gap between layers of metal conducts heat to the cookies much more slowly. This is because the two layers of metal are not in direct contact with each other. Heat moves from one layer to the next through radiation. This is a slower process than simply being conducted from the tray to the cookies. This allows the entire cookie to be baked by the hot air around it without the bottoms burning.

4.) A traditional tea kettle heats water through conduction. Energy is transferred from the heating element to the bottom of the tea kettle because they are in direct contact. Energy is then transferred from the kettle to the water that is in direct contact with the bottom of the kettle. As these water molecules gain energy they transfer it to adjacent molecules through conduction, and the overall temperature of the water increases. In addition, energy is also transferred through convection currents in the water. The warmer molecules (those with more energy) move up and transfer heat to other molecules. As they cool they sink back down and allow for a cyclical heating and cooling cycle. Eventually enough energy is gained by some water molecules that a phase change occurs (boiling). In a microwave, the water is heated through radiation. Rather than have the energy be transferred to only the bottom of the container, the energy comes from many directions to heat various parts of the water at the same time. In addition, the container is continuously turning, allowing for a more thorough heating. These aspects decrease the amount of time needed to heat the entire volume of water. This is because the energy is coming from many angles/directions and is able to directly affect more water molecules.

5.) A. Yes, a chemical reaction is taking place. On the macroscopic level it can be seen that two reactants are mixed. Styrene is a thick liquid and the hardening agent is a thin liquid. The product is a solid with different properties than either of the reactants. In addition, heat is produced.

B. The formation of heat indicates that the reaction is exothermic. In looking at this property of a reaction, it can be seen as a balance between breaking bonds (consuming energy) and forming bonds (releasing energy). In the case of an exothermic reaction, weaker bonds break to form stronger ones, and this results in the release of energy in the form of heat. To quantify this theory, I looked at the energy, in joules, of the reactants and products. One molecule of styrene contains one double bond between two carbons and three single bonds between hydrogen and carbon atoms. There were three of these molecules present and the total bond energy added up to $92.7 \times 10^{-19}$ Joules. On the product side, there were nine single bonds between carbon and hydrogen and five single bonds between carbon atoms. The total bond energy added up to $91.1 \times 10^{-19}$ Joules. These numbers suggest that more energy is present on the reactant side of the equation, which is indicative of an endothermic reaction. This is confusing because the reaction gives off heat.

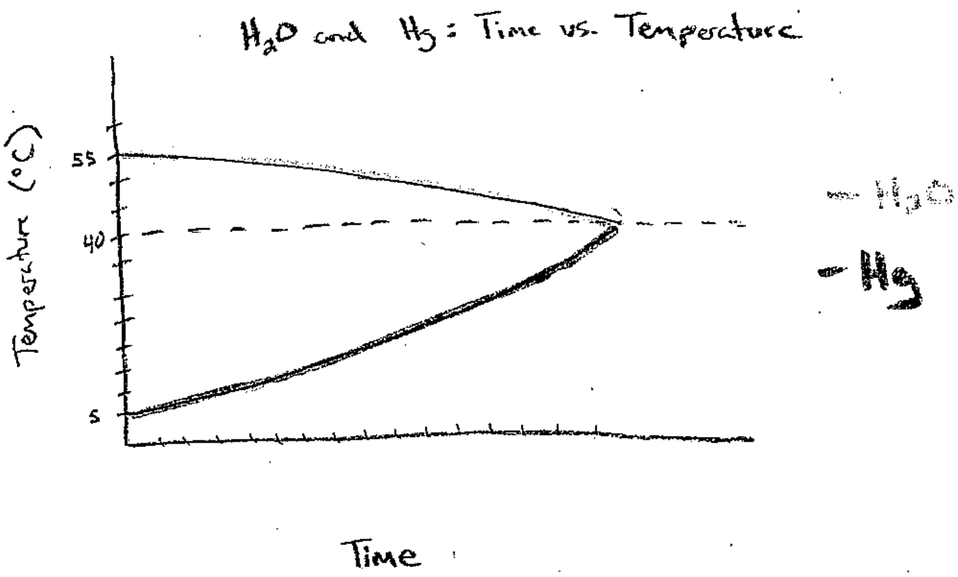
6.) A. As water moves through the radiator it is cooled by the air that flows through the honeycomb structure. It then flows through pipes attached to the engine. The engine produces heat when it is running and is subsequently hotter than the water in the pipes.

This allows for an energy transfer from the engine to the pipes and then the water. I do not believe that the pipes and the engine are in direct contact, so the initial heat transfer is through radiation. Then, heat is transferred from the pipe to the water through conduction. This transfer of energy helps to keep the engine cool. The hot water then travels back to the radiator and is once again cooled by the air flowing through the radiator.

B. One condition that would cause this cooling system to fail is if it is very hot outside and the air flowing through the radiator is not cooler than the water when it returns from the engine. Hot water then circulates through the engine and is unable to take energy from the engine. There is no cooling effect, but the engine continues to produce energy in the form of heat. Another possibility is that the water or other "coolant" solution could run out. When the solution is heated by the engine, some could evaporate. As the same solution continues to cycle through, more and more liquid volume could be lost. Eventually there would not be enough water to remove sufficient heat from the engine to allow for adequate cooling.

7.) A. I would expect the water and the mercury to be the same temperature when they are first poured into the container. Both had been sitting out in the lab since yesterday and have had time to reach thermal equilibrium with the room. While one may have reached thermal equilibrium sooner than the other, within a day's time they would have both reached this point. This is making the assumption that there are no other environmental factors affecting one more than the other.

B.




C. I disagree with this statement. The mercury is becoming warmer because heat is being transferred to it from the water. This means that the water is losing heat at the same rate that the mercury is gaining heat. The only way this would be different is if the two substances were not insulated in the container and there were other heat sources.

D. For this to occur, mercury's ability to gain heat would need to be greater than water's ability to lose heat. It would need to take less energy to increase the temperature of mercury compared to water because the temperature of the water only decreases by fifteen degrees, but the mercury increases by thirty-five degrees. I believe this could be due to the increased conductive ability of mercury (a metal). It is more efficient in its ability to transfer heat/energy, and less energy is needed to increase the overall temperature. Whereas in water, there would need to be either a greater volume or a greater temperature difference to lower the temperature more than fifteen degrees with this fixed volume.

Another way to think about this situation would be similar to that of a limiting reactant. In a fixed volume, there is more mercury than water molecules. The smaller number of water molecules limits the amount of heat that can be transferred. This causes the final temperature to be closer to that of water than to mercury.

8.) If a water bed is unheated, the water in the bed reaches thermal equilibrium with the room. This is significantly less than body temperature. When a person lays on the mattress their body heat is transferred to the mattress and then the water through conduction. This causes the person to feel cold. In addition, the mattress would be less firm when the water cools down. As the temperature increases the molecules move faster and the pressure within the mattress increases. This pressure makes for a firmer mattress, which would be more comfortable.

V17

1) The heat in a conventional electric oven comes from the processes of conduction and convection. The top and bottom heating elements are heated electrically through the direct transfer of heat through materials that are good conductors of energy (metal wires and metal structures). This heat is then spread through a mass movement of energy called convection. Some ovens have a convection fan to aid in the process by moving heat around the system. The color of the elements glows red at first because the elements are rising in temperature. As metal is heated through conduction, the color of it changes from orange to yellow and eventually to white at the hottest temperature. (which won't occur inside a kitchen oven).

2) When baking bread, conduction takes place through the lower element and heat travels through the metal baking pan. This heat works its way through the batter through convection which bakes the substance, starting on the outside and working its way inward to the center (the outside becomes crust and the inside is soft).

When cooking a steak, the broil element is used. Broiling is set at a very high temperature and cooks the steak through thermal radiation within close range from above the food. The steak is heated through infrared radiation, meaning the heat travels from the source to the substance through infrared rays.

3) The difference between a simple tray and a better tray is the air between the two metal sheets in the better tray. In a simple tray, the heat is being directly transferred from the element to the metal tray and then to the cookie dough. The narrow air gap in the better tray acts as an insulator. However, because air is not that good of an insulator, the heat still travels through the air and heats the cookie dough. The result is a less severe bottom because the heating/cooking was gradual instead of direct. The bottom of the cookies were heated at a pace that was more similar to the pace at which the tops of the cookies were heating.

4) In a traditional tea kettle, the water is heated through the conduction of heat. Although this means direct heat transfer, the heat has to move through two bodies (the heating element and the kettle) before it reaches the water.

Boiling water in a microwave is faster because microwaves heat things using thermal radiation. The heat travels from the microwave through the space in the form of infrared rays and directly heats the water instead of traveling through another body to reach the water. This makes for a fast process.

5a) Yes, there is an exothermic chemical reaction happening here. We know this because the pace is producing energy in the form of heat. This indicates that the product released more energy than the reactants absorbed.

5b) Input: 3(3(6.9) + 10.2) = 92.7 x10^-19 J

Output: 6(6.9) + 10(5.8) = 99.4 x10^-19 J

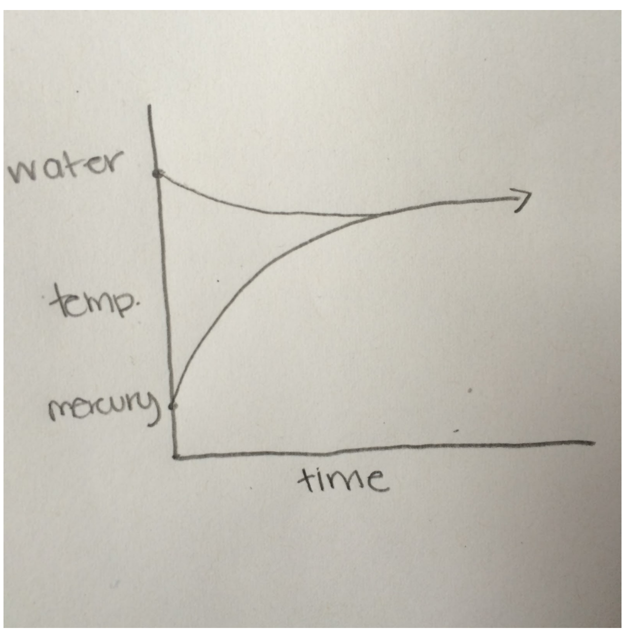
Positive Net Change: 99.4 - 92.7 = 6.7 x10^-19 J → exothermic chemical reaction

6a) The coolant is carried to the hot engine through the channels where it absorbs the engine's heat. The hot coolant is carried back to the radiator. The hot coolant expands and becomes lighter which allows it to rise. The heat from the coolant is transferred to the air through the radiator which acts as a heat exchanger. The now cooled coolant is fed back into the channels to the engine and the circulation process is repeated. Pumps and fans help to speed up this process.

6b) If the solution was just water (no antifreeze) and the climate unexpectedly dropped below freezing temperatures, the system would freeze up and not circulate correctly. If one were to let the coolant reach too low of a level, the coolant would begin to evaporate because of the heat from the engine. This would result in the system overheating which can cause damage to the engine.

7a) I would expect the water and the mercury to be around the same room temperature because they have both been sitting in the same temperature for the same amount of time and have been affected by the room's temperature.

7b)



7c) Yes, I agree with this statement because liquid mercury is a metal and uses free electrons to transfer heat and kinetic energy faster than water which doesn't have any free electrons.

7d) Because liquid mercury is a metal with free electrons, it is a better conductor than water. This means it is much more easily affected by the transfer of heat than water is and would be influenced by the heat from the heated water.

8) Unheated water beds are uncomfortable because there is no heat being transferred from the water bed to the sleeper. The water stays at room temperature which would feel cold to the sleeper. If you heat and circulate the water in the bed, heat will be transferred through conduction to the sleeper and make for a comfortable sleep. Unheated water beds could also result in condensation if the surrounding air is too humid. If you were to heat the water in the bed, this would prevent condensation from occurring and result in a dry mattress.

CHEM 444AH

# EXAM 2

1. At a molecular level, when the elements begin heating up, they atoms within them begin to vibrate more and more. This refers to a rather basic principle we have been discussing since the beginning of the class. The addition of thermal energy makes molecules vibrate and move more. As they continue to get hotter and hotter, and the vibration increases respectively, the molecules give off electromagnetic radiation. This radiation can be seen by the naked eye in the forms of color. On the color spectrum, everybody knows of ROYGBP. That is why the color begins as glowing red. Then, as it gets progressively hotter, it will travel down the spectrum. When it gets insanely hot, it will be "white hot." It appears white because you can see all the colors at once. So, as the elements gain heat, their radiation shows itself in color, and travels down the spectrum, often appearing red, orange, and then yellow.
2. When you bake bread, you are turning on the lower heating element on the bottom of the oven. Through convection, the heat will rise and circulate in the oven. This is why ovens must be preheated when baking. The internal temperature needs to be an even temperature. Then, this circulated air contacts the high walls of the bread pan, and through conduction, cooks the bread evenly from all sides. The molecules are vibrating throughout the metal at a similar rate, giving their energy to the break and baking it evenly. Broiling, on the other hand, requires the top-heating element to be turned on. This is because broiling is done by radiation. Radiant waves circulate around the top of the oven at a very high temperature, and then travel down upon the top of the steak, cooking it from the top down. This method is quicker for cooking, because the temperature is hotter and the heat is more direct to the food. As the radiation travel through the object, it speeds up the molecules and can cook
3. When the lower heating element is turned on to make cookies, the tray is placed on top. The metal tray, being a good conductor of heat, gets a lot hotter than the air circulating within the oven. This causes the bottoms of the cookies to cook faster, while the tops, receiving less direct heat, cook slower. This leads to a burnt cookie bottom. However, a tray that has a gap of air acts as an insulator. The air pocket heats up to the same temperature as the circulating air within the oven, and will cook the cookies evenly, and

preventing the bottoms from burning. This happens because as the bottom portion of the tray heats up, its molecules begin to vibrate more. These molecules must pass their energy through one tray, through the pocket of air, and then to the second tray level. This buffer acts as an effective insulator so that the tray does not heat up quicker than the rest of the oven.

4. When water is boiled in a teakettle, the bottom of the pot is heated. The molecules of water in contact with the bottom of the kettle begin to vibrate and heat up. This is the process of conduction. However, then those molecules begin the heat up and vibrate against the other molecules that are in contact. That is why this process takes longer – the molecules throughout the water aren't receiving the same amount of heat at the same time as the molecules towards the bottom of the pot. When water is boiled in the microwave, on the other hand, heat is radiated to the water from all sides. The molecules vibrate more readily, because molecules throughout the water are receiving heat at the same time. This causes the water to heat up quicker, but also unevenly sometimes.

5a. Yes, there is a chemical reaction occurring here. A chemical reaction occurs when two or more substances are combined to form a new substance with different properties. In this case, a thick, sticky liquid was combined with a hardening agent. Over time, this liquid became a solid, making it clear that a reaction occurred.

5b. This is an exothermic reaction. The heat is coming from the formation of bonds during the chemical reaction. For example, when people are shaking hands, it requires energy to break their bond. So, the opposite occurs when bonds are being formed. It is giving off energy, in this case heat, making the paste feel warmer.

$$3C_2H_3R \rightarrow C_6H_9R_3$$

BREAKING

H-C → $6.9 \times 10^{-19}$ (9) → $-9.27 \times 10^{-18}$ J

C=C → $10.2 \times 10^{-19}$ (3)

CREATING

H-C → $6.9 \times 10^{-19}$ (9) → $9.11 \times 10^{-18}$ J

C-C → $5.8 \times 10^{-19}$ (5)

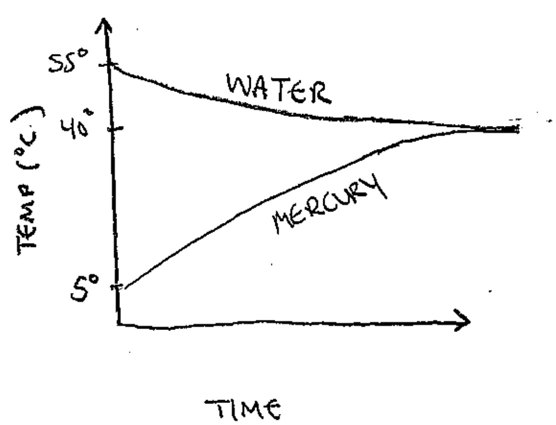
$\Delta E = -1.6 \times 10^{-19}$ J

6a. The radiator is placed in front of the engine. As the engine runs, it produces heat. Without the radiator, the heat would build up and cause the engine to overheat and be ineffective. However, because of the radiator's honeycomb-like structure, and that it is full of a coolant solution, evaporative cooling can take place. Air can pass through the honeycomb-like structure and evaporate some of the hot water that has been circulating through the radiator. When this evaporation occurs, the heat can then be released and the radiator can then send the cool water back to the engine, keeping it from overheating.

6b. This system might fail to protect the engine if the coolant solution or water runs out. When this happens, there is no way for the heat to exit. The heat would simply build up around the engine, cause it to overheat, and potentially break. Also, if the honeycomb was to somehow get clogged or break and air couldn't pass through efficiently, the heat wouldn't leave as quickly. Again, this would cause the engine to overheat. A third problem could be a clogged pipe that runs through the radiator. If the water can't circulate, the hot water will be trapped and won't be able to exit through the honeycomb. This would also cause overheating and damage to the engine.

7a. The two liquids are expected to be room temperature. They have been sitting out all night, and are poured into separate containers. A substance that does not react with either substance divides these containers, and it does not have a lot of thermal conductivity. As a result, these two liquids are likely to just maintain the same temperature of their surroundings.

7b.



7c. I do agree with this statement. It was stated that the box surrounding the container are thermally isolated from the rest of the lab. This would mean that the speed in which the substances reach their final temperatures is dependent upon what is occurring at the atomic level rather than what is going on outside of the container. However, the strip that separates the two liquids, while not being very conductive, is "modestly conductive." This could mean that the mercury could draw in some of the heat from the water and reach its final temperature slightly quicker, because of its superior conductive powers. It has the ability to pass energy around at a greater rate to it's own molecules, giving it the advantage over water.

7d. The initial temperature of the water was 55C, while the initial temperature of the mercury was 5C. They came to a thermal equilibrium of 40C, even though the masses of the liquids were the same. This is because there are more molecules per unit of volume in the mercury than there are in the water. Metals have free electrons, which can travel through the molecules and give off energy along with the vibrations of the molecules. These numerous molecules are vibrating against each with great speed, while receiving energy from the free electrons. This means that the mercury can heat up very quickly, quicker than the water can cool down. That is why the mercury and water came to an equilibrium of 40C, instead of the average of 30C.

8. Unheated beds were uncomfortable for sleepers because heat flows from warm bodies to cold bodies. The unheated waterbed would essentially drain the heat from your body through conduction, making you very cold at night, and probably very stiff and tight in the morning. We also discussed the process of homeostasis briefly in the readings of the desert squirrels. The body wants to maintain a constant core temperature and has many ways of doing that. However, when heat is constantly being drawn out during sleep, there is not a lot to be done to counter that loss except shiver. However, that also uses energy. Somebody would wake up feeling cold and tired if they slept on an unheated waterbed.

Chem 444A, Spring 2015, Exam 2 CFBauer Your Name: X15

Exam 2 is a take-home exam. It is due at my office (Parsons W108) or my Chem office mailbox (Parsons W115) by $\boxed{\text{4:30 pm}}$ Friday April 24. You may also deliver it to me electronically.

The exam covers predominantly the material since exam 1, but may overlap a bit with the early concepts unavoidably. The questions relate to the concepts and topics we discussed in class, so your primary resource is your own class notes, and the collective information on Blackboard.

There is no prohibition on use of resources. You can consult anything or anyone except the other students in class. However, all answers must be a construction of your own thoughts and words. The questions are intended to make you think and integrate ideas. You may not find a "ready answer" out there.

The exam is equivalent in length to the last one. I would expect it could be finished comfortably in two hours.

All responses should be legible, in grammatically correct sentences, and have an organized structure. Your goal is to use fundamental ideas in your response. Stronger responses will use those ideas more thoroughly and sensibly, describing WHAT but also HOW the phenomena occur.

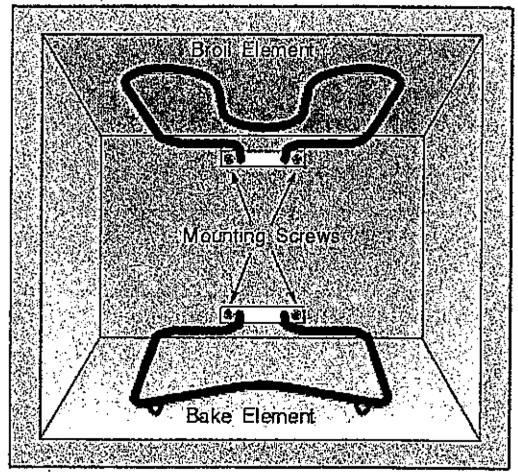
Each problem is 5 or 10 points as noted.

Chem 444A, Spring 2015, Exam 2 CFBauer Your Name: X15

Questions 1 to 4 are about cooking

Inside a conventional electric oven is a "heating element" on the bottom, and another "heating element" on the top: Here is a picture:

View: Inside Oven




1. When you "turn on" either of these elements, you will observe over time that the element at first looks unchanged although the air temperature inside the oven is increasing, then the element gradually starts to glow. First, it will be red. Later it will become orange or yellow. Explain where the heat and color progression of the glow come from. (10 pt)

2. To bake bread, you put dough in a metal container (like this)

And turn on the lower element to "bake" the bread.

To cook a steak, you put the steak on a metal sheet (shown to left) and turn on the upper element to "broil" the steak.

Compare and contrast baking and broiling in terms of how heat energy gets from the heating element to the material being cooked. (10 pt)

3. Baking cookies. You put cookie dough onto a flat metal tray inside the oven, and turn on the lower heating element. A simple metal tray often leads to burning the bottoms of the cookies while you are waiting for the tops of the cookies to get "done". Good bakers know that a better cookie tray has two layers of metal separated by a narrow air gap. The cookies on this tray don't burn – they are cooked just right throughout. Explain why the difference in the results. (5 pt)

4. Boiling water to make tea. Compare boiling water in a traditional tea kettle (shown here) and boiling water in a microwave oven. The kettle is placed on top of the oven on a circular heating element. The microwave oven brings water to a boil much faster (2 min compared with 5-10). Explain how the water is heated in both cases and why the microwave is faster. (10 pt)

Teakettle on stovetop: The water is heated by conduction only. Heat travels from the burner to the bottom of the teakettle & finally to the water inside.
Microwave: Radiation is the primary source of heat, it is much more concentrated & can heat the water much more quickly than a kettle on the stove. (Plus, it heats the air, so convection also heats the water somewhat.) The radiation from the microwave is much stronger than waiting for conduction to heat the kettle & the water inside.

1. The electrical energy generated when you turn on the oven is converted into thermal energy, since metals are good conductors of heat. As the heating elements' temperatures begin to increase + raise the temperature of the air in the oven, they begin to change color as a result of black body radiation. As the temperature of the metal increases, it emits more energy, which we can see as light + color. As heat + energy increase, the color of the metal moves along the electromagnetic spectrum. Different wavelengths correspond to different levels of heat + radiation, + we see the metal follow the electromagnetic path of colors as temp increases. Room temp. is black/grey, + slowly moves along the spectrum from red to orange to yellow to white, depending on how hot the metal gets + how much energy it is giving off.

2. For bread, conduction is mainly what occurs. Heat travels from the lower heating element to the bottom of the pan + the surrounding air. The heat that is transferred via direct contact between the heating element + the pan is then transferred to the bread dough in the pan so that it can cook. Radiation (from the lower heating element) + convection (from the heated air in the oven) also play a part, but the biggest difference between baking bread + broiling a steak is the significance of the role that conduction plays in each. The bread dough is in more direct contact w/ metal than the steak is, so conduction plays a more crucial part in breadmaking than in cooking a steak.
For steak, on the other hand, convection + radiation play a greater part in the process of broiling. The heating element emits radiation, which helps to heat the steak. It also heats the air in the oven, allowing convection to play a significant part in heating the steak as well. These two forms of heat transfer will both heat the tray that the steak is on, + via conduction, the heated tray will help to cook the bottom of the steak, but conduction does not have as significant a role as it does in breadmaking, where more of the bread's surface area is in contact w/ materials being heated by conduction (+ therefore heating the bread by conduction).

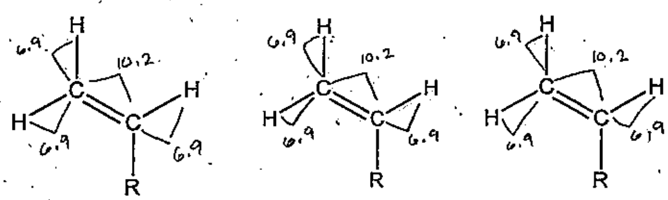
3. With a simple metal tray, the bottoms of the cookies are receiving the majority of the heat via direct conduction — the lower heating element in contact w/ the tray, + the tray in contact w/ the bottoms of the cookies → so the bottoms get done first. Since the tops of the cookies are in contact w/ only the air, not the tray, they are being heated by convection from the heated air + take longer to cook — so by the time the tops are done, the bottoms are burnt.
However, if there is a narrow air gap between 2 metal layers of the tray, conduction is delayed. Conduction first occurs from the heating element to the lowest layer of the tray, + then heats the air in between the layers. Finally, that air gap heats the top layer of the tray via convection, + conduction heats the bottoms of the cookies in contact w/ the uppermost layer of the tray. Because the bottoms of the cookies are delayed a bit in this way + the tops are unaltered, they take close to the same amount of time to bake. The air gap adds another step to the process, slowing down the baking of the bottom of the cookies so that they cook roughly as slowly as the tops.

Chem 444A, Spring 2015, Exam 2 CFBauer Your Name: X15

Questions 5 and 6 are about automobiles.

5. Bondo is a commercial product used to repair holes in the exterior body of cars, e.g. rust holes. It is a thick sticky liquid, but you mix it with a "hardening agent" and that converts the liquid into a solid over about 15-20 minutes. So, you take a "handful" of the liquid, mix in a few drops of the hardening agent, and then use a putty knife quickly to transfer the paste, and mold and shape it over the hole. The liquid is primarily a substance called styrene. The "hardening agent" starts a process which converts the styrene into polystyrene, which is a solid. Both structures are shown below.

This shows 3 molecules of styrene. R is a complex group of atoms that are not affected by the process.

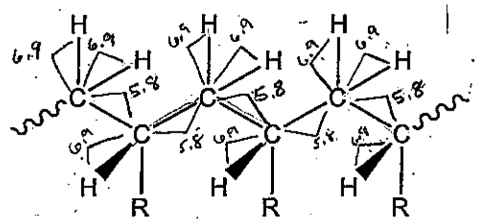


$10.2 \times 3 = 30.6$
$6.9 \times 9 = 62.1$
$\overline{92.7}$

Reactants: 92.7

$5.8 \times 5 = 29$
$6.9 \times 9 = 62.1$
$\overline{91.1}$

Products: 91.1 → endothermic reaction ?



This shows the polystyrene segment that comes from three molecules of styrene. The squiggly lines at the end of the polystyrene indicate that the chain of C atoms continues (if more styrene molecules are involved). The chain can be 100s of units long.

must be exothermic right?

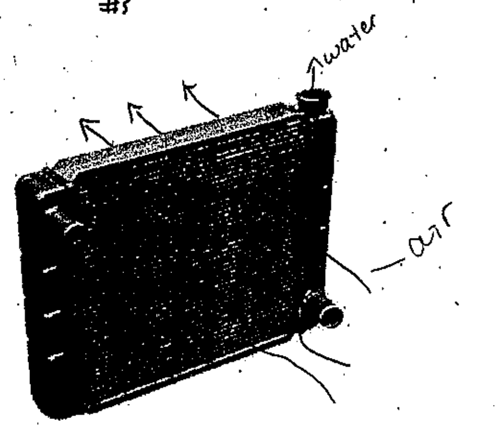
Here's the question (finally): One time I was repairing my car and noticed that the paste as it was hardening was warmer to the touch than it had been at the start. I confirmed this with a thermometer.

5a. Is there a chemical reaction going on here? Justify your answer. (5 pt)

5b. What is the source of the heat? A better answer will include a quantitative argument. (5 pt)

#5

6. Most cars have a "radiator", made entirely of metal, like this:




You fill it with water (or a special "coolant" solution). A pump circulates the water into the bottom and out the top, and then through metal pipes (not shown) that attach to the engine, and back to the bottom of the radiator again. The flat part of the radiator is a honeycomb structure. Air can move through that honeycomb. The radiator is normally placed at the very front of the engine compartment. The engine produces heat when it is running.

a. Explain how the radiator protects the engine from overheating. (10 pt)

b. Suggest two conditions under which this system might fail to protect the engine. Explain why those conditions would cause a problem. (10 pt)

5.a. Yes, a chemical reaction is occurring. The combination of the two substances, styrene + the hardening agent, combine to create a new substance that is neither of the initial reactants, polystyrene. Bonds are breaking & new bonds are formed, creating the new product.

5.b. My calculations & the observation that the paste was warmer as it solidified do not seem to match up. The styrene (92.7) plus whatever energy the hardening agent has yield a product of 91.1, which would suggest that it is an endothermic reaction — more energy is being absorbed by the breaking of the bonds. But if it gets warmer, then that implies that it is exothermic, & more energy is generated when bonds form, so the product has more energy than the reactants. But if my calculations are correct, then it's the <u>opposite</u> — the reactants have more energy than the products. The only solution I can think of is if the hardening agent has negative energy (I don't know if that's possible), or if it reacts with the styrene in such a way that it loses energy, & more energy is released via forming new bonds than it is absorbed via breaking the bonds of the reactants. i.e.:

$$\underset{(92.7)}{\text{Styrene}} + \underset{(-2,\ \text{for example})}{\text{hardening agent}} \longrightarrow \underset{(91.1)}{\text{polysterene}}$$

...but I don't know if a negative amount of energy in the reactant is even possible. That's the only thing I can think of.

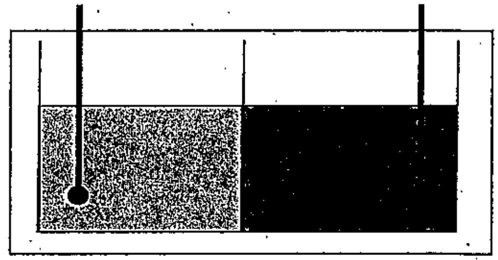
6.a. Air moves through the honeycomb part of the radiator when the car is moving, which cools the water/coolant being pumped through the radiator. As the water travels through pipes to the engine & back to the radiator, excess heat from the engine is transferred to the water in the pipes. In this way, excess heat is removed from the engine so that its temperature is regulated & it doesn't overheat. When the water gets back to the radiator, it is cooled off again by the air moving through the radiator & the process is repeated.

b. 1) On hot days, the air blowing through the radiator to cool the water may not actually be that cool, & may not be able to cool the water enough for it to be able to cool the engine in turn. Especially if the air conditioner is running & the engine is already working more than normal & generating more heat, the radiator might not be enough to keep the engine from overheating.

2) Another condition would be if there happened to be a leak somewhere, leading to the depletion of coolant/water. If there isn't enough water, the small amount of water that is left will not be able to move as much or as quickly & as a result will not be able to remove heat from the engine efficiently.

Chem 444A, Spring 2015, Exam 2 CFBauer Your Name: X15

7. Consider this scenario.



Two containers share a common wall.
Identical thermometers are in each.
The container on the left contains water.
The container on the right contains mercury, a liquid metal.

The wall separating the containers is a substance that does not react chemically with water or mercury, and it has modest thermal conductivity. The box shown surrounding the container indicates that the materials on the inside are thermally isolated from the rest of the lab.

a. Assume the water and mercury had been sitting out on the lab bench since yesterday. Describe what you expect the temperatures of the two liquids to be just after pouring them into the containers. Explain your expectation. (5 pts) The two liquids would be roughly the same temperature, if not exactly the same temperature. Over the time that they had been next to each other, whichever substance was warmer at the start would have transferred some of its thermal energy to the wall between them + through it, the other substance. After long enough, they should reach thermal equilibrium (zeroth law of thermodynamics).

b. Assume that you had removed the mercury from a refrigerator, and had warmed the water in a microwave before. Then you poured the liquids into the container above. The initial temperature of the water is 55 °C and mercury is 5 °C. Sketch a graph showing both temperatures over time. Label appropriately, but only worry about qualitative accuracy not quantitative accuracy. (10 pts)

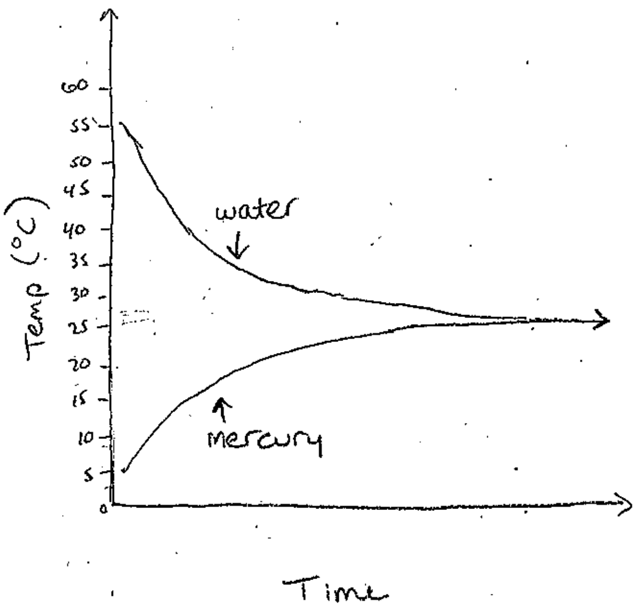
c. Another students says: "I expect the mercury to reach its final temperature more quickly than the water will because mercury as a metal is a better heat conductor". Do you agree or not with this statement? Explain: (5 pts) I don't entirely agree. Although the molecular structure of metals (w/ their free-moving electrons that can absorb & react to increases of thermal energy more quickly) does allow mercury to reach its final temperature more quickly than it would if it weren't a metal... →

d. The number of molecules or atoms per unit volume is slightly larger for mercury vs water. Nevertheless, the final temperature will be about 40 °C, closer to the initial temperature of water. Explain how that could result. (5 pts) Since mercury has a higher density + more molecules per the same amount of volume, the molecules will be able to absorb more thermal energy & move more quickly—the more molecules there are, the more they will bounce off each other & the more kinetic energy they will generate, resulting in a higher temperature than if the substance had lower density & fewer molecules per unit volume. Because mercury can absorb more heat due to its molecular structure, the final temp will be higher than it would if both liquids had the same density.

8. Water beds were common in the 70s. They had a number of drawbacks: they are really heavy when filled (structural problem in a house), if they spring a leak there could be serious water damage, and it's necessary to circulate and heat the water, otherwise sleeping on an unheated water bed is very uncomfortable. Explain why unheated beds were uncomfortable for sleepers, using fundamental principles. (10 pts)

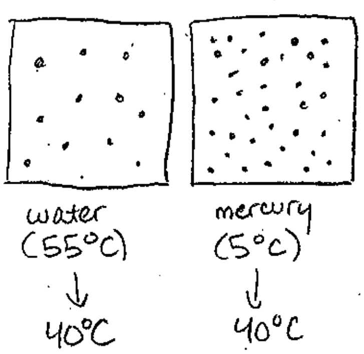
First of all, your body temperature naturally drops as you sleep. Second of all, despite the fact that your body temp will be lower than it was when you were awake, you, as a living being, will still possess more heat than an unheated water bed. As a result, as you sleep, heat transfer will occur & thermal energy will be transferred from your body to the water bed, & you will be left with an even lower than normal body temperature. Although temp. is meant to drop while you sleep, you would lose an inordinate amount of heat in this situation, which would make sleeping very uncomfortable because you would be too cold.

b.




c(cont). because mercury is a good conductor & can absorb the transfer of thermal energy from the water quickly, both substances are changing at roughly the same rate. Mercury conducts heat from the water quickly, so the water's temperature & thermal energy decrease in direct proportion.

d. same volume, but mercury has more molecules:



Y13

Chem 444A, Spring 2015, Exam 2

1. Within the name of the oven itself you know that the heat will be transferred through convection, which is a movement of matter. This means that the air within the oven circulates due to temperature differences. The hot air rises since it is less dense and the cool air sinks since it is denser. The density difference is due to the amount of energy within the molecules of the air due to temperature and the fact that they expand with heat and are more compact when cold. The process of convection happens by convection currents circulating the air and heating. This relates to cooking because in order for the food to be cooked evenly the whole object must be exposed to the heat. The heat begins to increase when you turn the oven on and set it to your desired cooking temperature. When the oven is turned on it signals the large coil wires to begin heating up. They heat up due to electricity which would be them receiving heat through conduction, which is due to direct contact of the molecules. Since it is a convection oven fans are running at the same time to circulate the air. The color progression of the metal is due to the metal warming up and not necessarily reaching its melting point but coming to a temperature where physical changes appear. The colors become lighter and more vibrant the hotter the metal becomes. That is why the burners and pans are made of different metals.

2. Broiling works by exposing your food to direct heat from the source above it. It works by quickly searing the outside of your food and ultimately warming the inside because it is at a constant temperature of 550 degrees Fahrenheit. Broiling is a heat transfer due to conduction, which is a heat transfer due to direct contact of molecules. Baking works by surrounding your food with the hot air produced by the oven. It usually takes longer than broiling and it ranges in temperatures between 170 degrees Fahrenheit and 500 degrees Fahrenheit. Baking transfers its energy to the food through convection, which is when the air around the object circulates and causes a movement of the molecules.

3. The simple metal tray causes burning because it promotes uneven cooking. Some parts of the pan could be hotter/ heat up quicker than others and it is providing the heat through conduction due to the direct contact with the cookies. Also, metal heat transfer is a lot easier/faster than air heat transfer so the metal pan will become hotter than the air around it thus cooking the bottom of the cookies a lot faster than the top. This is because with the metal pan the cookies are in direct contact with the pan which is in direct contact with the metal rack of the oven. As for the two layer metal sheet, the gap in the metal allows for an even temperature to be provided

throughout the pan because it allows convection currents to circulate the air as needed. The pan then provides the heat transfer through conduction to the cookies as well but the temperature being transferred will be more consistent throughout the whole pan. This is because the part of double layer pan that touches the cookies is not touching the metal wire racks directly and is only being heated by hot air in the oven and not added heat from the metal-metal heat transfer.

4. In the microwave the heat is being transferred by radiation, while the tea pot is transferring heat through conduction. Both of these heat transfers are a molecule to molecule transfer. Radiation works by energy waves being emitted from the heat source and coming in contact with the other object. Conduction works by direct contact of the molecules and them influencing each other's temperature to reach thermal equilibrium between the teapot and water. While on the other hand the burner is constantly increasing in temperature and influencing the teapot to increase in temperature as well. The microwave is better/faster, and therefore radiation, because electromagnetic radiation is easily absorbed by food due to the fact that there is no medium needed for the heat transfer. With radiation the beams of radiation quite literally heat the source directly so it is receiving all of the heat.

5.

a. Yes there a chemical reaction because there is a physical change that can be seen in the material as well as the production of heat while changing. You could physically see that the substance was changing from a paste to a solid which shows that something had to occur on the molecular level to change the state of the substance. It shows the bonds between molecules began to strengthen since it went from liquid to solid.

b. It takes energy to break bonds and it releases energy to form bonds. So the chemical reaction is molecules are forming bonds to go from a pasty liquid to a solid. Bonds are forming intermolecularly and when bonds form they give off energy. So the heat comes from this exothermic chemical reaction.

6.

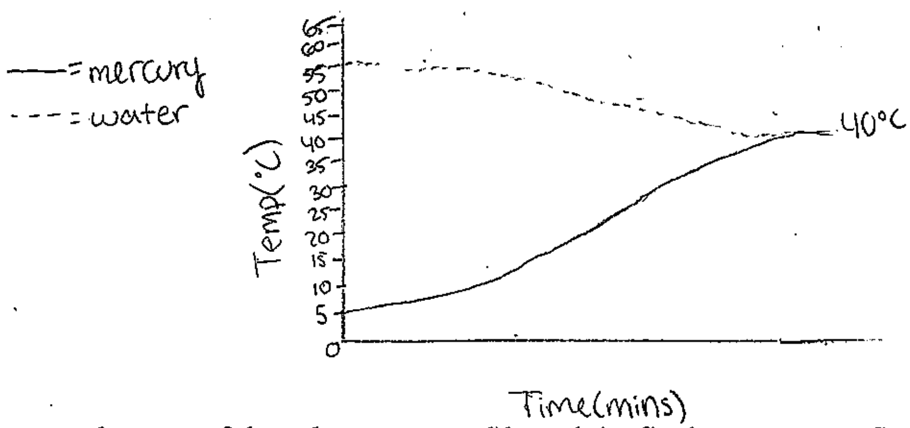
a. A radiator protects the engine from overheating because it disperses the heat away from the engine. To do this there is a coolant that flows through the radiator hoses. These hoses span through the engine and a flexible enough to move with vibrations. The water pump is what pumps the coolant throughout the whole cooling system and to the engine block. Cooling fins surround the core and as air passes through these fins the coolant releases its heat. When it releases its heat to the fins the heat is then dispersed so there is not an overwhelming effect that would cause the car to overheat. So overall the radiator protects the engine by absorbing and dispersing its heat away from the engine itself.

b. The age of the radiator is the most common cause of failure to prevent the engine from overheating. After about 5 years the radiator begins to not function properly. One of the most common things to occur for a radiator over time is rust. The rust will slowly decrease the radiators capability to accomplish its tasks of cooling the engine because the rust will continue to form and eventually take over and degrade the radiator. Another problem is if the coolant cannot flow through the tubes unobstructed then the radiator would fail to protect the engine. This is because it will not be able to cool the radiator effectively and if it cannot properly have the coolant flowing through its system then the engine will overheat. Common causes come from mineral deposits building up in the smaller tubes throughout the radiator system.

7.

a. The temperatures would reach thermal equilibrium because they share the same walls and the middle wall would still conduct the heat and transfer it between liquids. They are also being exposed to the same outside environment so there are no outstanding factors to effect it.

b.




c. I disagree that one of the substances would reach its final temperature first because if it did the temperature difference would continue to cause a heat transfer. The heat transfer would affect both substances ultimately changing both of their temperatures, meaning that neither had reached their actual final temperature. So in order to eliminate further heat transfer both substances would need to reach their final temperatures at the same time.

d. Water's mass specific heat is 4.18 j/(mol*k) whereas mercury is .14 j/(mol*k). So even though there is more mass of mercury in this scenario there would need to be a mass ratio higher than the specific heat ratio of 4.18/1.4. That implies there is about ~~twenty~~ four times more mass of mercury than water where as in the problem the ratio is closer to one. All in all, it takes a lot more energy to change water's heat than mercury's so the final temperature stays closer to water.

8. Unheated waterbeds are uncomfortable for sleepers because it is constantly drawing body heat from the person sleeping. Some people may be fine with this but others find it to be unbearably cold because since you are so much smaller than the water bed it draws away more heat from you and never really increases in temperature because you cannot provide enough for a reasonable thermal equilibrium. Due to this your temperature will go down to one closer to the water beds temperature. Since your body's temperature decreases it will kick in as if you are in danger and begin to work harder to maintain the correct internal temperature. The ground draws energy from the water bed and the water bed draws energy for you. The ground will be colder than the bed and the bed will be colder than you. The bed will then pull the heat from you while it is still being constantly cooled by the ground. Ultimately pulling the heat from you into the ground. This will cause sleepers to feel uncomfortable if they do not like the cold and for that reason many water beds come with a thermostat to keep a stable temperature of the water inside so that the sleeper is comfortable.

Exam 2
24/4/2015

Z11

1. When an oven is turned on, energy in the form of electricity begins to flow to either the top or bottom element. When electricity is carried through either elements, it glows red, orange, and yellow. This can also be seen in light bulbs, the filament of is producing light as electricity is run through it. The light being produced by electricity running through the filament, or in this case the oven elements, is made by heat. The red, orange, or yellow glow is from the heating of and flow of electricity through the element, to such hot temperatures.

2. When baking bread, you turn on the lower element and set it to a certain temperature. In modern day ovens, there is even an option for "convection bake." This circulates the hot air to make the temperature throughout the oven uniform, allowing the bread to cook all the way through. When cooking a steak in the oven, you set the oven to broil, which turns on the upper element. Instead of setting the temperature as you would with baking, broiling brings the temperature to the highest it can. Broiling transfers heat through radiation, especially as the food is close to the upper element, in order for the heat (in the form of light/infrared) to radiate to the food. This allows for the food to become charred, as if it were being cooked on a grill.

3. Using a cookie sheet with a narrow air gap allows for air to flow between the sheets, also known as convection. When using a cookie sheet that is a single layer, the bottom of the cookies are directly touching metal, a very good conductor, which will cause the bottoms to cook much faster. Therefore, allowing convection between the two layers keeps the metal the cookies are directly touching to be at a closer temperature as the air that would be cooking the tops of the cookies. The convection between the layers allows the hot and cooler air to interchange, keeping the metal at a temperature closer to the air.

4. Boiling water with a traditional tea kettle transfers the heat from the element of the stove to the teapot by conduction. The water at the bottom of the teapot, closest to the metal heats up first. Once the water at the bottom is heated, the rest of the water begins to heat up as heat is transferred. A microwave uses

Z11

radiation as a transfer of heat. Radiation heats up the molecules of water evenly, as opposed to the bottom first (like a teakettle). This allows a microwave to heat water faster than boiling a tea pot on the stove.

5. a) A chemical reaction is occuring when the two substances are combined. This can be proven by the change in properties of the substances, from a liquid to a solid. Once combined, the reaction releases heat, another characteristic of a chemical reaction.

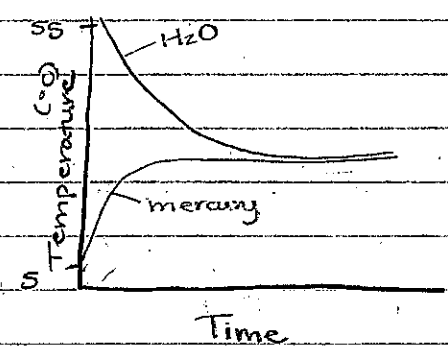
b) The source of heat in this reaction is the formation of new bonds, because heat is released, it is an exothermic process. This means the amount of energy released as a part of the formation of new bonds is greater than the amount of energy absorbed when the bonds are broken apart. For example: when the carbon (single) carbon bonds are formed, $5.8 \times 10^{-19}$ J are released. In the example of 3 molecules of styrene, 7 bonds are formed, resulting in $40.6 \times 10^{-19}$ J of energy released. The process of breaking the carbon-carbon double bonds absorbs $10.2 \times 10^{-19}$ J per molecule, so 3 molecules equals $30.6 \times 10^{-19}$ J. Therefore the amount of energy released is $10.0 \times 10^{-19}$ J greater.

6. a) The radiator prevents the engine from overheating by allowing the water/"coolant" solution to cool and then run through the metal pipes around the engine. As the coolant is run around the engine, the heat produced by the engine heats the coolant (transferring the heat by conduction if they are touching or convection if they aren't touching and depend on the flow of air [I'm not sure if they touch, but one of these processes are at work]). Once the coolant is transferred the heat, it flows back to the radiator, were it can cool off due to the flow of air and its proximity to the cooler outside environment.

b) This system might fail to protect the engine on extremely hot days because it is more difficult for the coolant to cool off in the radiator because the outside environment is close in heat and the coolant can't absorb much more heat as it flows back to the engine. Another problem could be a low level of coolant. Without enough coolant has similar effects as a hot day. When the coolant flows around the engine, there isn't enough liquid to absorb/remove the heat from the engine.

7. a) If both the water and mercury have been sitting in the same environment for about a day, I would expect them to have similar temperatures unless they were kept in an insulated container. Sitting out for a day allows the substances to heat or cool, no matter their insulating properties.

b)




c) I would agree with the student who says that mercury would reach its final temperature faster than water. This is due to the specific heat level, the amount of energy necessary to add in order to change the temperature. Water has a high specific heat level which means more energy needs to be added to change the temperature, while metals, like mercury, have low specific heat levels. This also explains why they are good conductors.

d) The final temperature is closer to the water's initial temperature because of mercury's low specific heat level. Less energy needs to be put in for mercury to change its temperature, while a lot more energy needs to be put in water to change its temperature.

8. An unheated water bed is very comfortable because the cold water absorbs the heat from your body. This occurs through the process of conduction, your body is directly on top of a colder surface so heat is transferred. The heat then absorbed in to the water bed then circulates through all that water, and the water continuously drains heat away from your body, making the sleeper very cold.